THE EFFECTS OF TAMARISK REMOVAL ON DIURNAL GROUND WATER FLUCTUATIONS

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Technical Report NPS/NRWRD/NRTR-96/93

WATER RESOURCES DIVISION

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ON DIURNAL GROUND WATER FLUCTUATIONS

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The Effects of Tamarisk Removal on Diurnal Ground Water Fluctuations

ABSTRACT

The National Park Service conducted a demonstration wetland-riparian restoration project at Sacatone Wash, Lake Mead National Recreation Area, Nevada during 1992-1994. The project involved removal of the exotic tamarisk (Tamarix ramosissima) and revegetation with native plant species. Nearly three years of water level monitoring spanning periods before and after tamarisk removal revealed a variety of daily water table fluctuation patterns. Tamarisk removal eliminated a significant pattern of daily fluctuation thought to be associated with the evapo-transpiration of ground water. A similar fluctuating pattern reappeared two years later after re-establishing native vegetation. Water consumption before was similar to two years after tamarisk removal. It appears that the tamarisk community was replaced by other species that consumed approximately the same quantity of groundwater. Comparison of the data from this study to historical work by W. N. White (1932) indicates strong similarities in water level fluctuation patterns. Thus, use of White's formula to estimate water loss due to evapo-transpiration by tamarisk was determined to be applicable to this situation.

INTRODUCTION

Tamarisk (Tamarix ramosissima), an exotic phreatophyte, has firmly established itself throughout the southwestern United States in areas of shallow water tables. In addition to altering native riparian plant community structure and changing wildlife values, tamarisk lowers water tables through high transpiration (Gatewood, et al, 1950).

Horton (1977) noted that once well established, tamarisk will persist unless removed by human manipulation or natural perturbation (e.g., scour by floods). The objective of this project was to remove tamarisk plants from the Sacatone Wash riparian zone, replant the site with native woody vegetation, and document the effects of this vegetation conversion on shallow water tables. The project involved cutting tamarisk along the wash where density was low enough to allow reasonable access. The slash was stacked against remaining tamarisk thickets and then burned (Appendix A). Any post-burned tamarisk growth was removed through a combination of cutting and application of the herbicide Garlon IV. Planting of native species was supplemented through seeding, transplants, and root stock. Revegetation was largely successful through natural recruitment.

In most shallow water-table wells, water levels fluctuate almost constantly. In the growing season, this is due chiefly to the periodic character of evaporation and transpiration from plants. The water level may also fluctuate over longer periods due to pumping or heavy precipitation. Earthquakes may produce fluctuations of greater or lesser magnitude. Fluctuations in water tables may also be produced by changes in stage, or level, in hydraulically-connected rivers or lakes (White, 1932). Fluctuations are an expression of a change between the rate of ground water supply, or recharge, and the rate of loss or discharge.

A hydrologic monitoring network was installed below the spring at Sacatone Wash to document the effects of tamarisk removal and re-establishment of native vegetation on riparian zone hydrology. The network was composed of six shallow wells with digital recorders. Climatic data were also available for the site and are discussed later in the report.

GENERAL FEATURES

Location

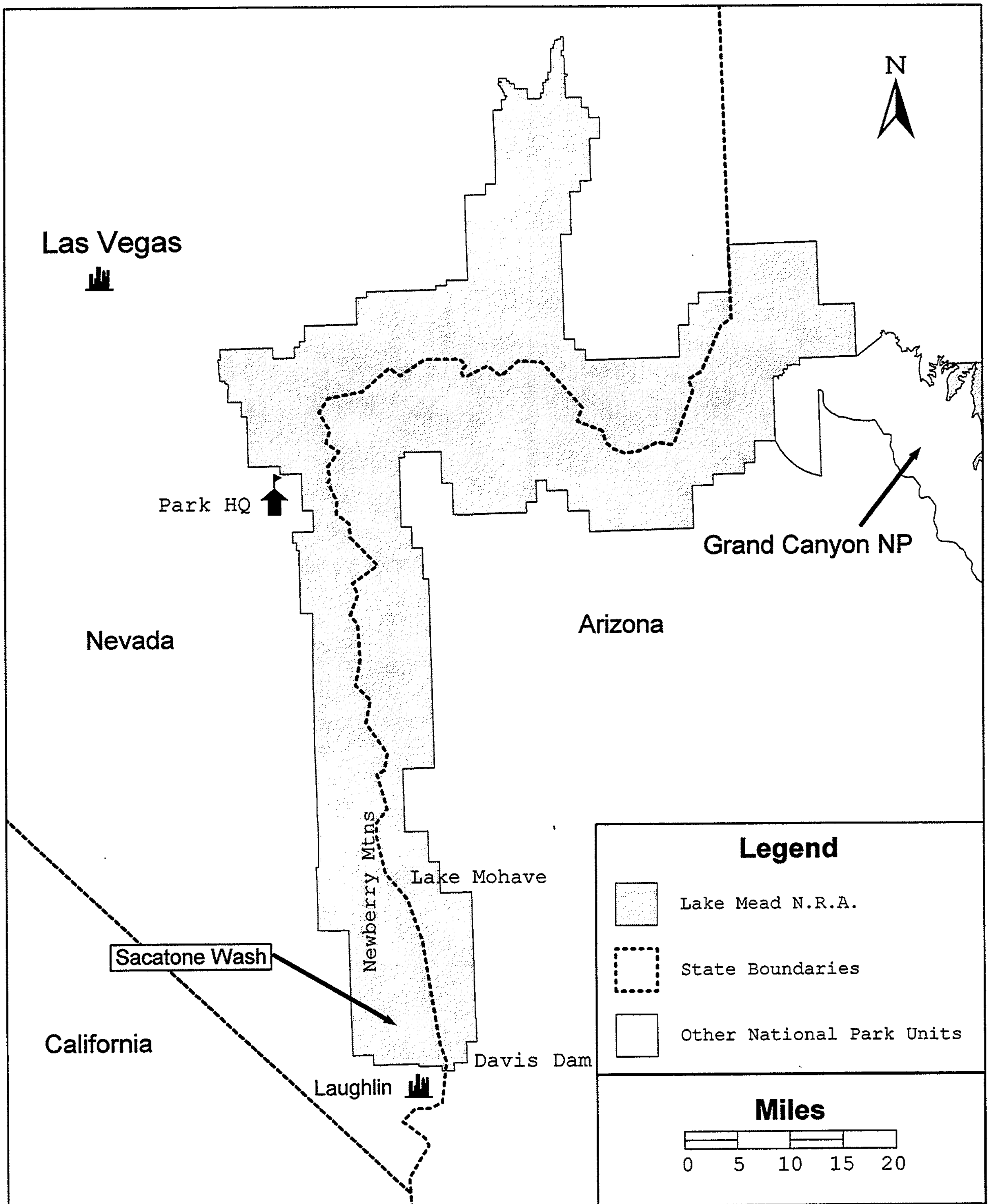
Sacatone Wash is located about 10 miles northwest of Laughlin, NV and 70 miles south of Las Vegas (Figure 1). The valley of Sacatone Wash has a length of about 5 miles and a width of about 1 mile. The watershed above the spring covers an area of about 5 square miles. It lies on an east aspect of the Newberry Mountains and drains into Grapevine Creek and then into Lake Mohave. The Newberry Mountains, which form the western divide of the watershed, reach an altitude of 5,600 feet. The mouth of Grapevine Creek at Lake Mohave is at an elevation of 640 feet. The Newberry Mountains are extensively fractured granite and the resulting soils are mostly coarse sand. The wash is characteristic of a Mohave/Sonoran Desert wash, with mesquite, cat claw, desert baccharis and desert willow being the dominant native vegetation. Where present, tamarisk excludes most all other vegetation.

Topography

The terrain in the Sacatone Wash area is sharply dissected and of relatively high relief. Average slopes are about 20 percent but range between very steep on rock outcrops to less than 5 percent on ridge tops and benches. The spring emerges at an altitude of 2200 ft (Figure 2). The stream gradient throughout the study area is 4.5 percent.

Vegetation

Sacatone Wash has vegetation comprised of Mohave and Sonoran species. The four major vegetation communities in the Newberry Mountains are the Encelia, Larrea-Ambrosia, Mixed Shrub and Mixed Shrub-Woodland Communities (Holland, 1982). Several cactus species, Yucca shidigera, and red brome (Bromus rubens, an exotic annual grass) are also found on the hillsides immediately adjacent to the study site.



Lake Mead National Recreation Area

Figure 1. General Location Map of Sacatone Wash

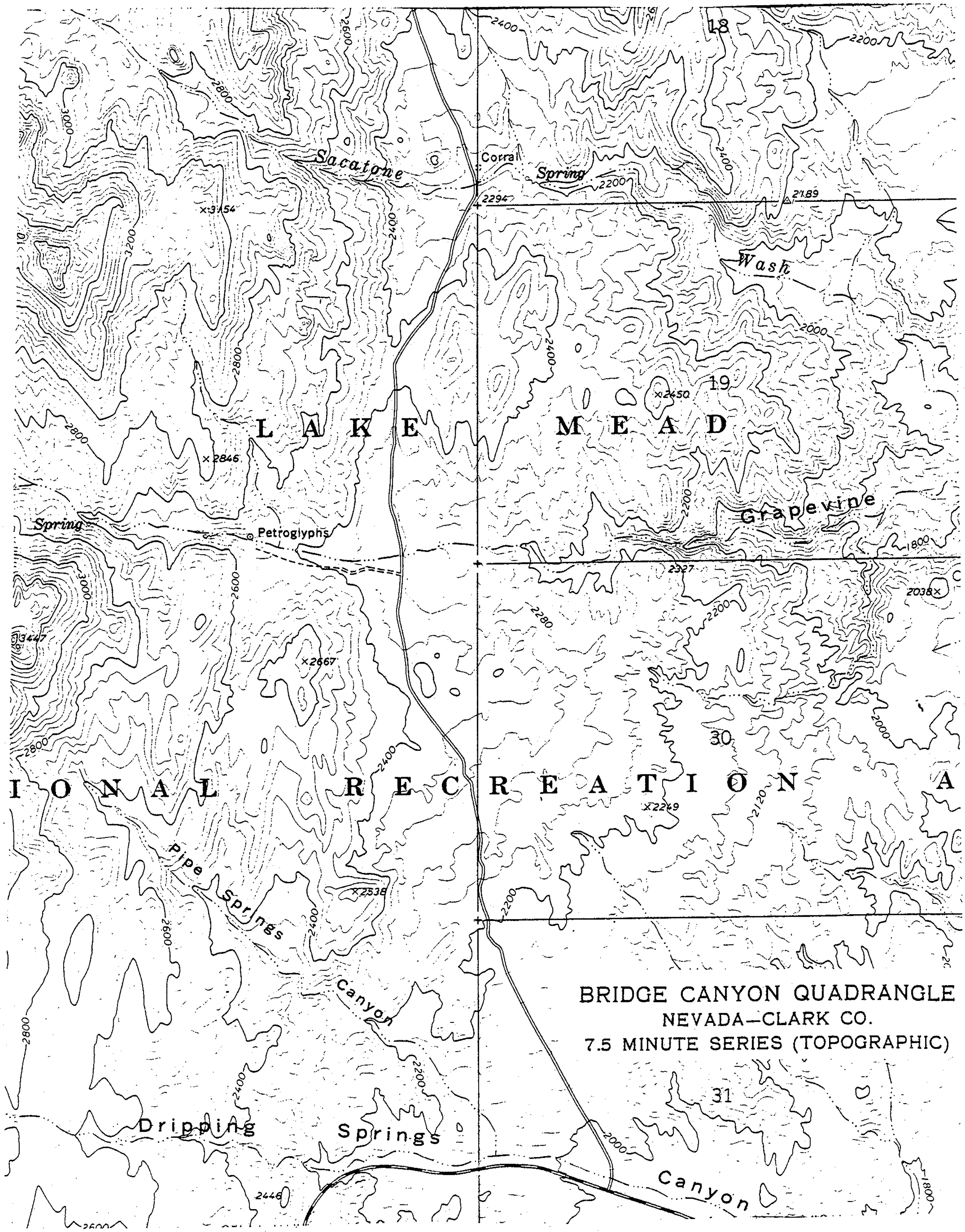


Figure 2. USGS Topographic Map of Sacatone Wash 1:24000

Sacatone spring supports a narrow band of riparian plant communities. The exotic tamarisk (Tamarix ramosissima) dominated the study site before the study treatment, forming nearly continuous thickets along the stream banks. Native tree species present to a much lesser degree include cottonwood (Populus fremontii), willow (Salix goodingii, S. exigua), mesquite (Prosopis glandulosa torreyana, P. pubescens) and cat-claw (Acacia greggii). The most common shrubs are Baccharis sergiloides, arroweed (Pluchea sericea), and wolf berry (Lycium torreyi). Mature stands of Sacatone grass (Sporobolus airoides) are found throughout much of the wash bottom. Emergent vegetation, including Typha sp., and Juncus sp., is also present. After tamarisk was eradicated from the drainage, native tree species listed above comprised the majority of revegetated species.

Precipitation

The climate of Sacatone Wash is arid and is characterized by hot summers and mild winters. The average annual precipitation is about 5 inches in Lake Mead NRA and ranges from about 3 inches in the lower altitudes to about 10 inches in the mountains. The average annual precipitation is 3.5 inches at Davis Dam, about 3 miles east of Sacatone Wash, and is 7.6 inches at Searchlight, which is 20 miles north west of the study area at an elevation of 3,540 feet.

A rain gage was maintained for most of 1992 at the study area. Rainfall was also recorded for three years at a site called Catacombs, about a mile away and slightly higher in elevation than Sacatone Wash. The record of precipitation thereby obtained (see Table 1) shows the great seasonal variability of rainfall patterns at the site. 1992 was an unusual year in that nearly three times the average precipitation was recorded.

Month	1992 Sacatone	1992 Catacombs	1993 Catacombs	1994 Catacombs
Jan	ND	1.61	2.25	0.0
Feb	2.66	4.05	5.03	0.0
Mar	5.53	7.77	2.35	1.30
Apr	0.11	0.28	0.0	0.0
May	0.21	0.16	0.41	.06
Jun	0.0	0.0	0.31	0.0
Jul	0.0	0.05	0.0	0.32
Aug	0.18	0.62	0.32	ND
Sep	0.0	0.0	0.0	ND
Oct	1.03	2.07	0.0	ND
Nov	0.0	0.0	0.0	ND
Dec	0.8	0.0	0.0	ND
Total	10.52	16.61	10.67	1.68

Table 1. Precipitation at and near Sacatone Wash

Geology and Soils

Granitic and metamorphic rocks form the main masses of the Newberry Mountains. The oldest rocks exposed in the area are granite, schist, and granitic gneiss, all of Precambrian age. These rocks are the lowermost barrier to the movement of ground water. The granitic and metamorphic rocks generally do not yield water except along fractures and weathered zones.

The younger alluvium of Holocene age is exposed in stream channels and small flood plains in the mountains and in channels and flood plains on alluvial slopes. This alluvium is composed of unconsolidated sand and gravel. The unit generally is drained; however, in places in the mountains where it is underlain by impermeable rock, the younger alluvium may be partly saturated and yield small to moderate quantities of water to wells (Bentley, 1970).

Weathering of the Precambrian rock has resulted in soils of coarse sand and almost no clay. From this description, the specific yield of this material was estimated to be 25 percent, which is considered high for most aquifers (Campbell and Lehr, 1973).

Stream Discharge

Stream flow in Sacatone Wash is typically ephemeral. Much of the stream channel is wide and braided above and below the study area due to heavy sediment loads. This indicates the flashy nature of runoff in response to storms in desert arroyos having a relatively steep gradient. The thin, coarse soils and shallow depth to bedrock in the watershed results in rapid runoff and little retention of moisture. The channel within the study area is more vegetated than upstream and is confined within banks, indicating less erosion during storm runoff than similar sites up or downstream.

The 1992-94 study was unusual in that surface flow occurred throughout most of the period. These flows are attributed to several large rain events during the first year. Stream flow was not recorded continuously during the study, but periodic estimates range from 0.014 to 11 cubic feet per second (see Table 2). Low flow measurements were taken using volumetric methods and higher flows used channel dimensions and a float to determine velocity.

Ground Water Conditions

Sacatone Spring (as marked on the USGS topographic map in Figure 2.) is believed to be the key source of water for the tamarisk-dominated wetland. The spring probably issues from a fracture in the bedrock and the recharge area is probably the higher regions of the Newberry Mountains. For most years, the spring flow is not substantial enough to support perennial stream flow of any distance. This is born out by the lack of any tamarisk more than 0.25 mile downstream from the study area.

Date	Est. Stream Flow (cfs)
Feb 25, 1992	0.014
Apr 1, 1992	6.0
May 14, 1992	0.9
Jun 3, 1992	1.2
Jul 1, 1992	0.3
Jan 20, 1993	9.7
Feb 22, 1993	11.
Mar 11, 1993	10.
Apr. 23, 1993	5.0

Table 2. Discharge Estimates for Sacatone Wash

Spring flow, consequently, recharges the alluvial aquifer of Sacatone Wash with the water moving down valley until consumed by evapo-transpiration or lost to deeper aquifers through other fractures in the bedrock.

During an April, 1991 (wet season) site visit, 20"-40" holes were augered along transects perpendicular to the stream to get some idea of the hydrologic conditions in the alluvium adjacent to the stream (Wagner, 1991). Holes augered within a few feet of the spring filled rapidly with water, indicating presence of a high water table in a substrate with high permeability. Further away from the stream (approx. 50 feet) the alluvium deepened and the water table was not encountered within 35-40 inches of the surface. However, observation of low chroma soil matrix with bright colored mottles at about 30 inches below the surface indicated that the water table, at least historically, reached that level through spring recharge and local rainfall. Tamarisk may have lowered water levels to the extent that these soil indicators may be relics of the previous water regime.

Detailed Site Description

The study area was divided into 7 units for vegetative mapping and monitoring of the prescribed burns (Figure 3.). The units were generally 100 ft. by 200 ft. rectangles aligned with the length of Sacatone Wash. Approximately 40 percent of the study area was covered with tamarisk before treatment. Sacatone Spring is located in Unit #2. The upstream monitoring wells were located in Unit #3, and the downstream wells were in Unit #5. The remaining thicket of tamarisk, Well 3 and Well 4 were in Unit #4.

Included in the monitoring project are data from three of the nine vegetation plots that were within the immediate vicinity of the three water table monitoring locations (upstream, middle and downstream) during the hydrology study. The vegetation plots were sampled during the first week of June in three consecutive years (data are included in Appendix B). Pretreatment sampling in June, 1991, was before any vegetation manipulation, prior to

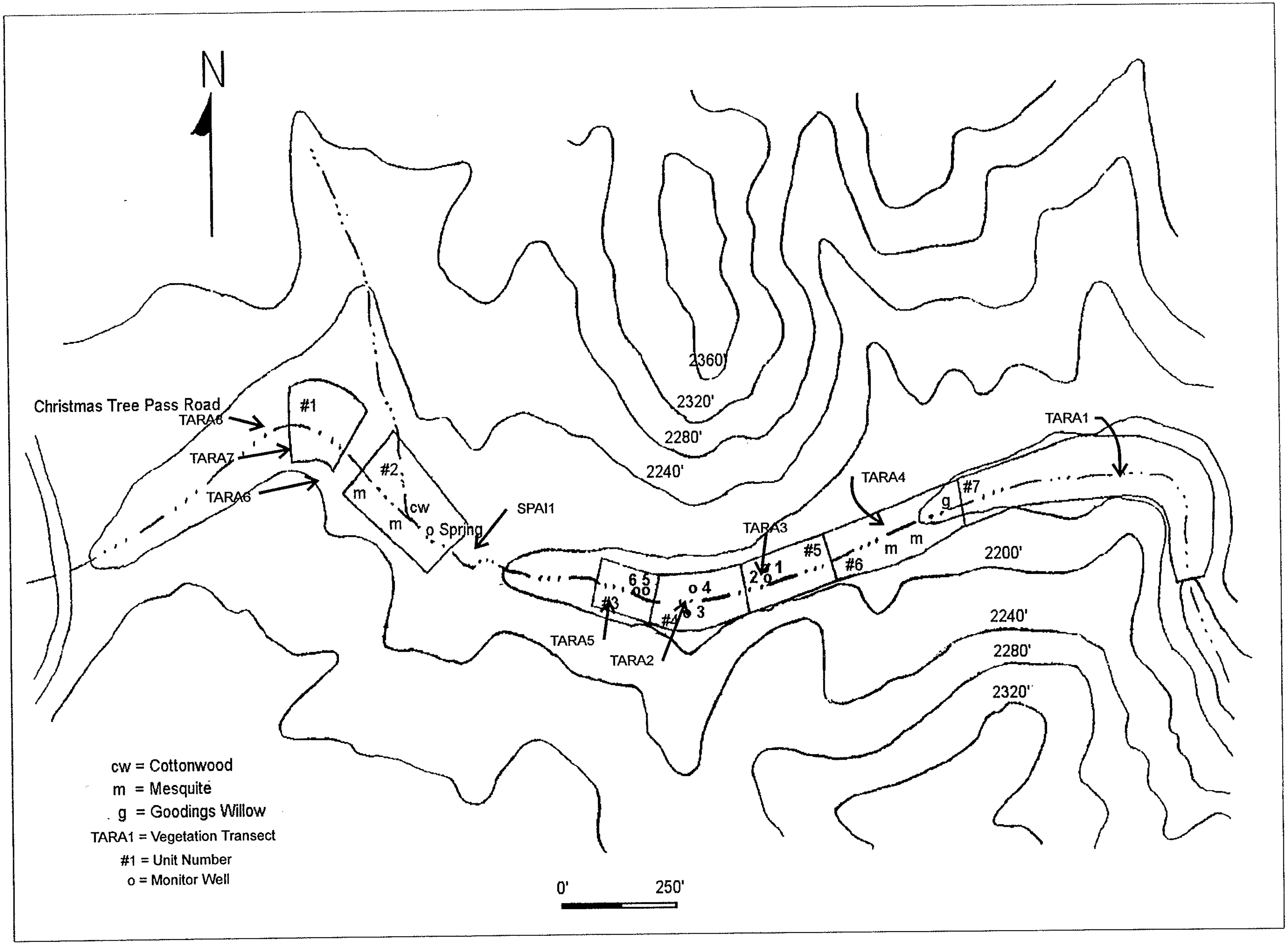


Figure 3. Detailed Site Map Showing Vegetation Units and Well Locations

tamarisk control and the prescribed burn. The burn took place in December, 1992. Vegetative sampling in the first year after treatment occurred in June, 1993. The most dramatic vegetation changes occurred during the second year after manipulations in June, 1994. A summary of the data collected is included in Appendix C (Taylor, 1994) on all nine of the fire effects transects.

METHODS

Study Objectives

A study plan was prepared to guide monitoring efforts for this restoration project (Wagner, 1992). The objective was to monitor water table fluctuations in the vicinity of a tamarisk thicket before and after removal of the thicket and to provide water table data to guide revegetation.

Hydrologic monitoring was initiated after most of the tamarisk was cleared from the study area with the exception of Vegetative Unit #4. The remaining thicket (centered over Well 3 and partially over Well 4) was left to stand in 1992 for a year of "pretreatment" monitoring. The other four wells were located in cleared areas previously covered with tamarisk.

Observation Wells

Three hydrologic monitoring sites were initially chosen next to the channel of Sacatone Wash; upstream, downstream, and within the remaining thicket of tamarisk (Figure 4). Each of the 3 sites consisted of two 2-inch diameter PVC wells (replicates) inserted in holes augered to bedrock ranging from 20 to 38 inches deep. The replicate wells were about 3 to 6 feet from each other. The bottom opening of each well was wrapped with plastic screen. The holes were back filled outside the casing with augered material. Wells were flushed of sediment by pouring water down a 1-inch tube to the bottom of the well until clear water flowed out of the well. A standard measuring (reference) point was marked on the top of the well casings and the wells were capped.

Recorders

Pressure transducers were placed in each well and connected to digital recorders set to read at 30 minute intervals. Water levels were checked with a tape measure approximately once a month in each well for calibration purposes. Pressure transducers recorded relative water level changes, while measurements during field checks are absolute to reference points.

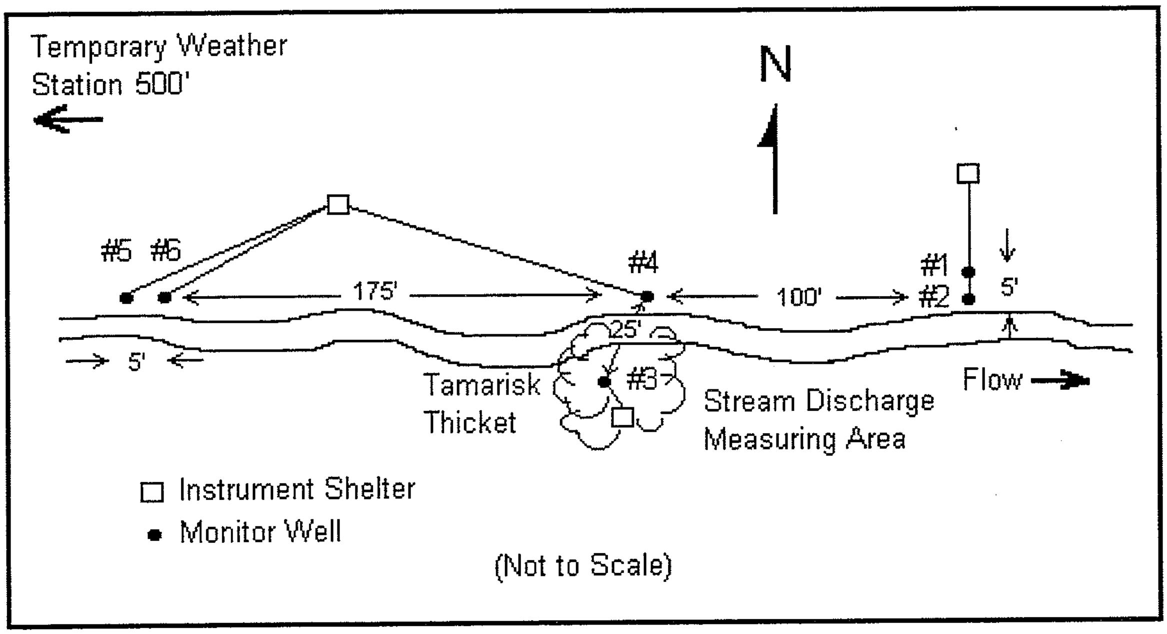


Figure 4. Map of Hydrologic Monitoring System

Data Collection

The wells and recorders were installed February 25, 1992 at the three sites after clearing most of the tamarisk. For 1992 and 1993 data were collected on a continuous basis with several exceptions for equipment maintenance. In 1994, about two weeks of data were collected in late July and early August when the recording equipment was removed on August 3, 1994 (Figures 5, 6 and 7). During the study, several major rainfall events affected the hydrology and the nature of the stream channel in Sacatone Wash (see Table 1). Flood depths up to 4 feet were recorded before the recorders were submerged and terminated the record during several storms in February, 1993. All wells were overtopped and Well 3 was scoured out and destroyed. In the immediate study area, portions of stream banks were heavily eroded, while in other locations, extensive deposits of sediment occurred. Before this storm Sacatone Wash was dry, however the stream flowed continuously for the remainder of the study period. In late February, 1993, Well 3b was reinstalled in approximate pre-flood locations, flushed of sediments and re-equipped with new water level recorders after the storm. It was decided to report relative changes in water levels for this study due to loss of survey benchmarks and equipment during the flood.

Soil Measurements

Field tests were conducted to determine hydraulic conductivity of the alluvial material found in Sacatone Wash. A simplified version of field saturation was attempted but results were dismissed as unreliable. Techniques from irrigation engineering were tried later on Well 3b with better results. Hydraulic conductivity was calculated using an auger hole method developed by Dr. S.B. Hooghoudt (Luthin, 1978) with results of about 30 meters per day (m/day). This was cross checked using an equation developed by Kirkham (Luthin, 1978) for a pipe-cavity method with results of about 75 m/day. Kruseman and deRidder (1991) give orders of magnitude of hydraulic conductivity of different rock types and unconsolidated material. For coarse sand they give a range of 20 - 100 m/day. Kruseman and deRidder also provide a representative value of specific yield for coarse sand of 27 percent.

Treatment

Nine long-term vegetation plots were established prior to cutting of the majority of tamarisk (1991) using guidelines from the NPS Western Region Fire Monitoring Handbook. Prescribed management fires require a burn plan which addresses ignition procedures, fire control methods, equipment and personnel needed, along with a prescription including weather conditions and fire behavior predictions. The goal of the prescribed fire is to consume and kill shoots of standing trees and eliminate cut and slash piles. Removing large monotypic stands of tamarisk using the cut stump method is extremely labor intensive, creating slash piles which are usually burned after a few months of curing.

The last tamarisk stand and slash piles at Sacatone Spring were ignited the first week of

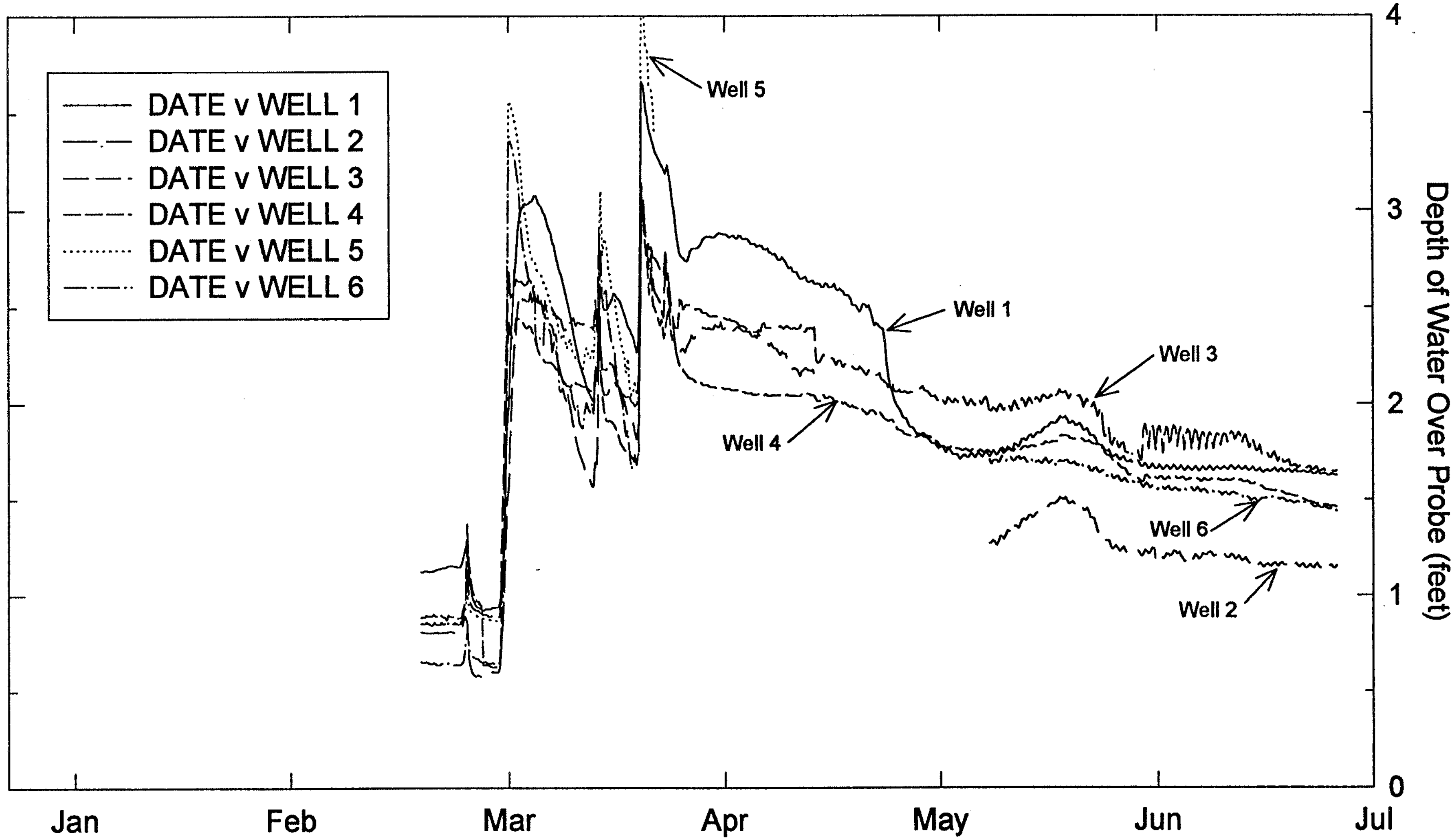


Figure 5a. Water Level Plots During First Half 1992

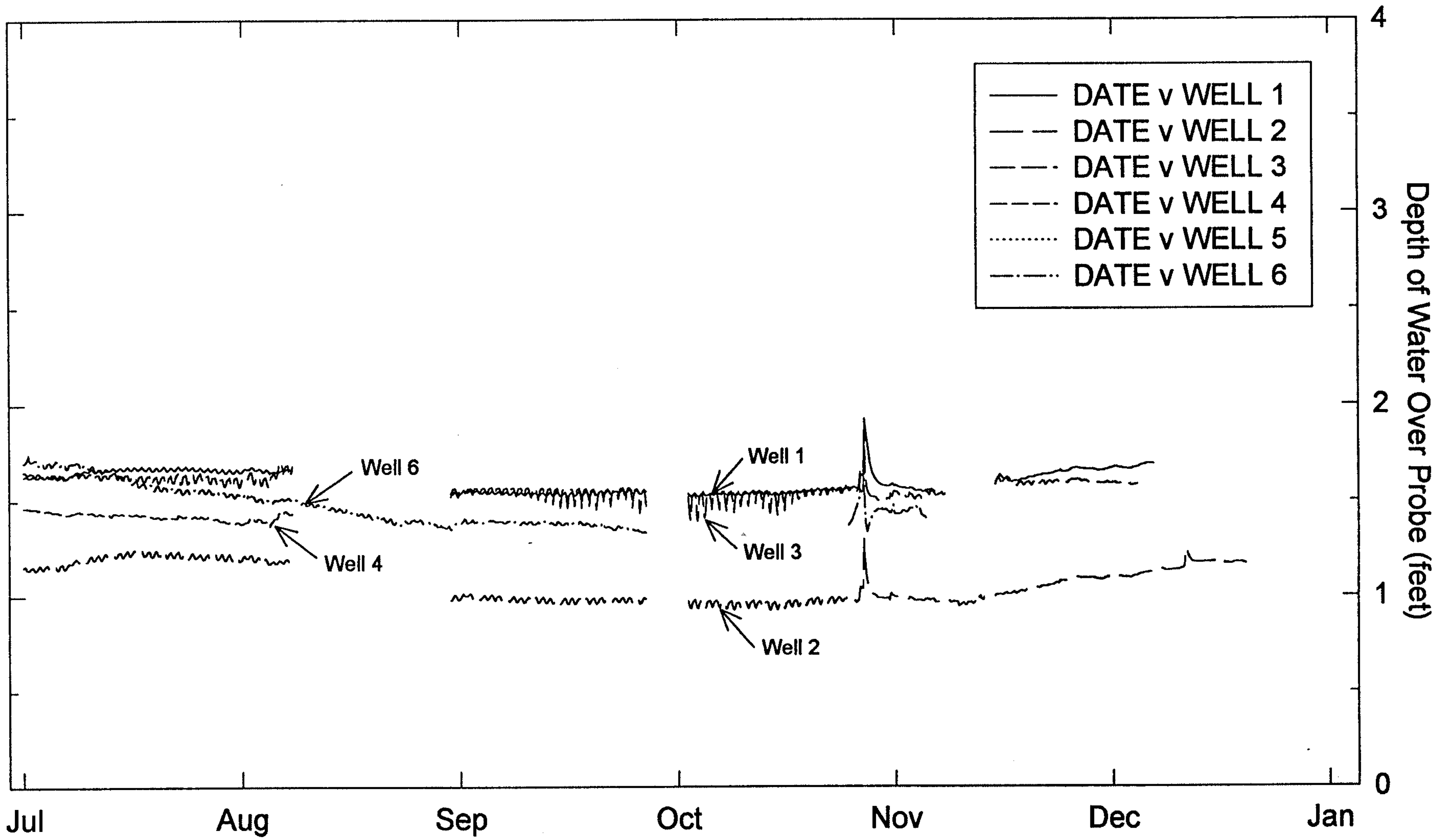


Figure 5b. Water Level Plots During Second Half of 1992

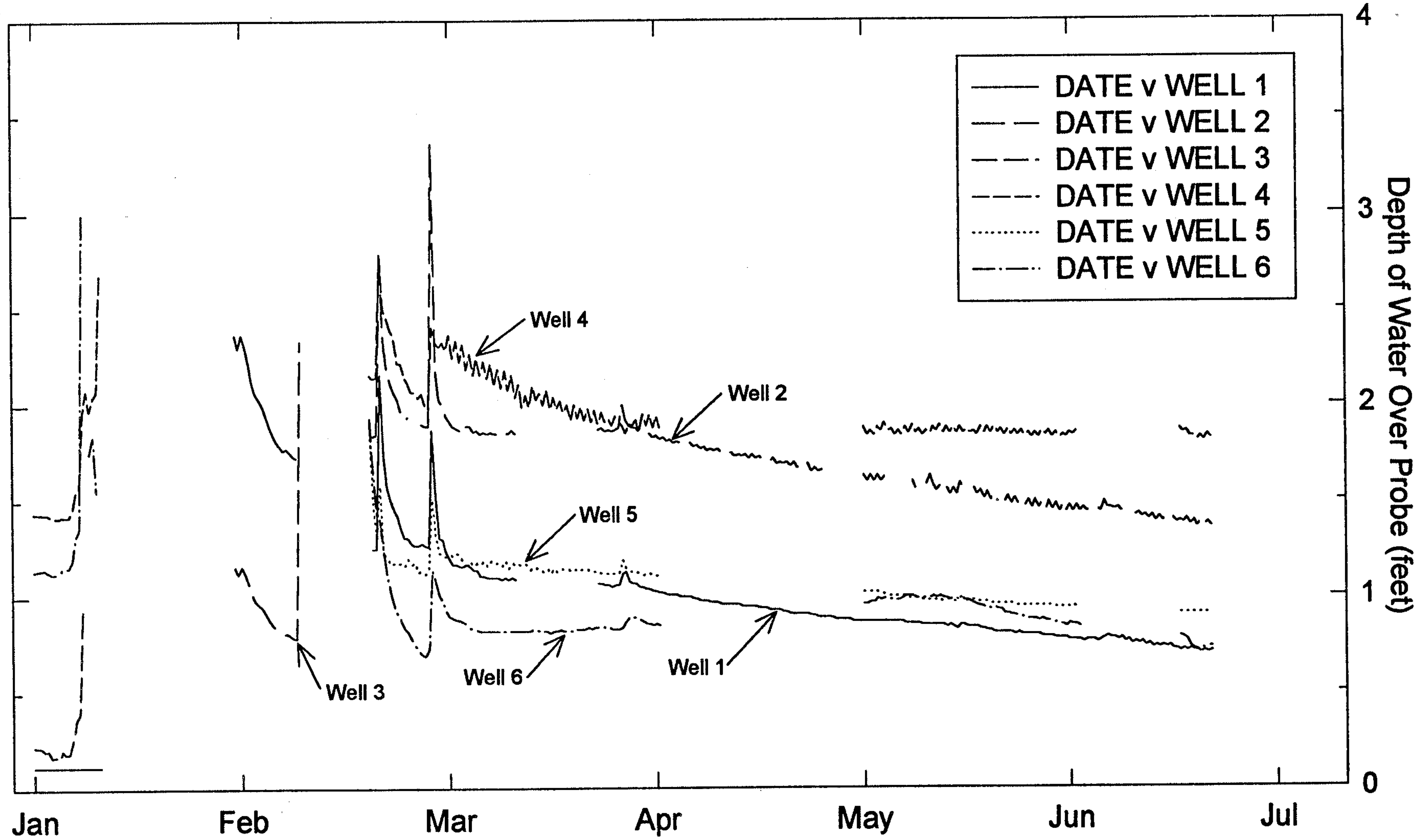


Figure 6a. Water Level Plots During First Half of 1993

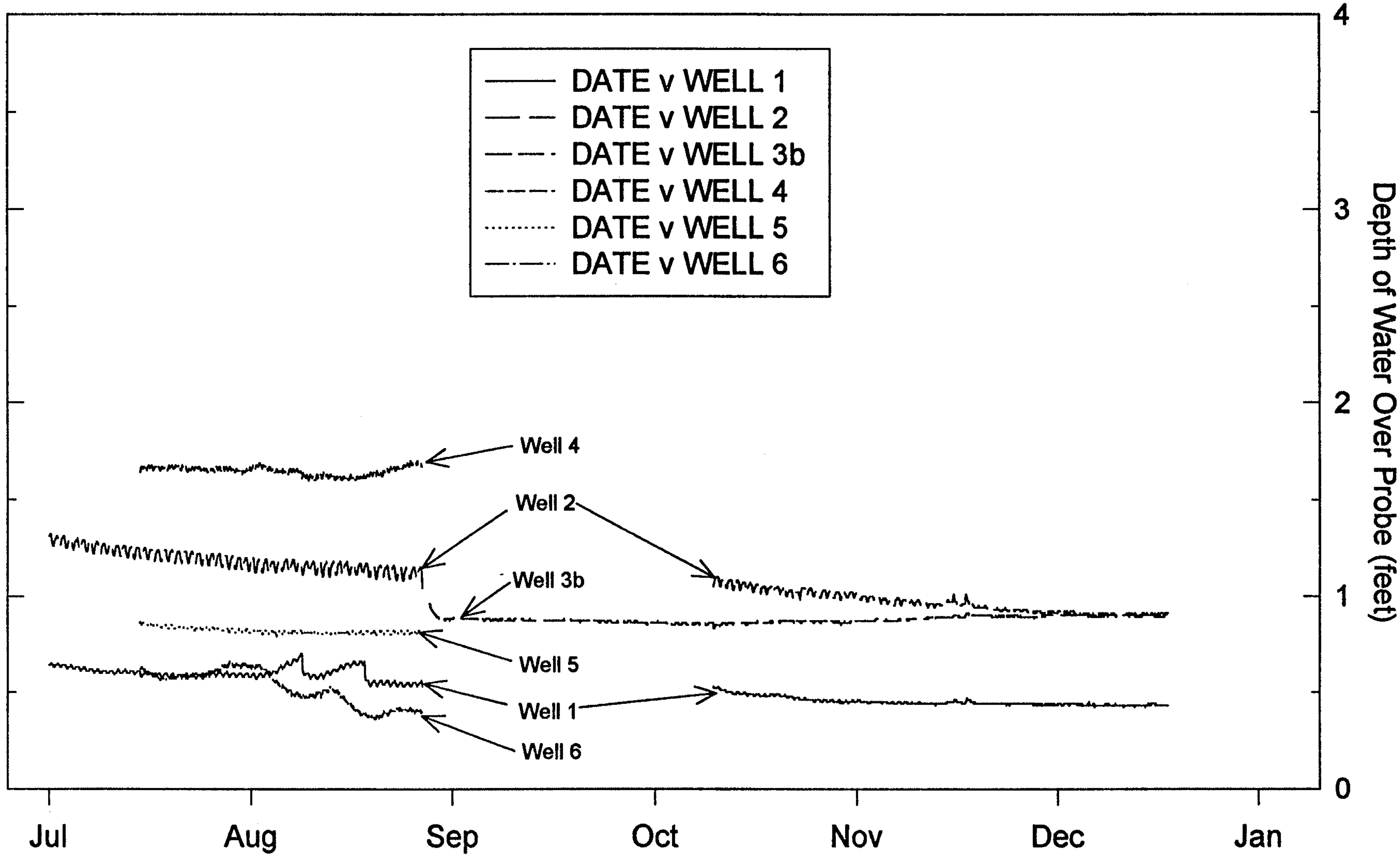


Figure 6b. Water Level Plots During Second Half of 1993

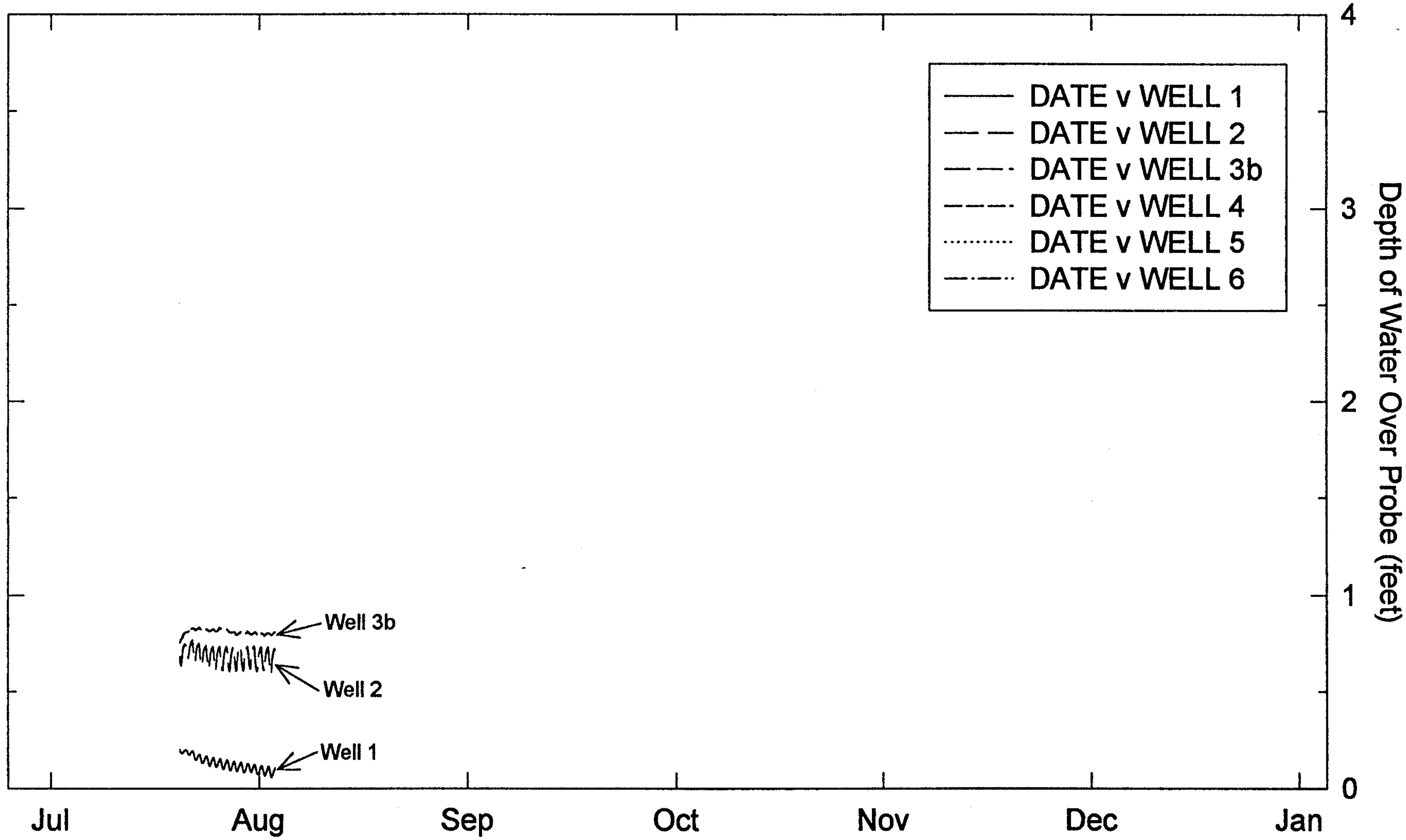


Figure 7. Water Level Plots During Second Half of 1994

December 1992 when live fuel moistures were 150 percent over dry weight (tamarisk can maintain over 250 percent live fuel moisture throughout the summer). Various fire behavior results were documented and a great deal of knowledge was acquired for future burns. The tamarisk sprouted vigorously after burning, although an estimated 10 percent mortality was observed. The formerly impenetrable thickets of tamarisk were then easily accessible by herbicide applicators using the low volume basal method (hand spraying one to two feet above ground level depending on the diameter of the trunk).

The cut stump and low volume basal herbicide application methods together are probably the most effective and reliable way to control large (>15 centimeters in diameter) scattered tamarisk trees. Chainsaws, loppers, and gas powered shoulder harnessed brush cutters were used to cut each tree at the base, leaving a short stump as close to the ground surface as possible. Straight Garlon 3A or Garlon 4 mixed with Penevator Basal Oil was applied to the cambium layer circumference immediately following cutting. Garlon 4 and oil resulted in at least 85 percent mortality rate while Garlon 3A was estimated at 75 percent. Garlon 3A is preferred in areas where surface water contact is unavoidable due to its low aquatic toxicity.

Replanting needs at Sacatone Spring were determined by the amount of existing native plants before undergoing tamarisk control. The object of restoration and site recovery is to re-establish sustainable populations of native plant communities with the combination of transplanting and natural recruitment after tamarisk stands have been removed. Due to their high wildlife value and for competition against future tamarisk establishment, the focus of the Sacatone Spring revegetation efforts concentrated on re-establishing mesquite (Prosopis glandulosa, and P. pubescens), cottonwood (Populus freemontii), willow (Salix goodingii and S. exigua), and catclaw trees (Acacia greggii).

One gallon and five gallon container sized trees were transplanted during the winter and spring months. Trees were planted within the areas where tamarisk had been removed, with specific locations determined according to depth to the water table. Tubex tree shelters were installed around each transplant to protect from herbivore predation and to promote growth. Seeds from various shrubs and forbs collected on site were spread on burn sites in February, 1992. Site preparation included soil surface scarification with hand rakes before and after seed spreading, however, no apparent seed germination from sown seeds has occurred.

Transplant survival rates were estimated at 75 percent of about 250 plants with impressive growth after the first season. Natural cottonwood recruitment occurred (several new seedlings), eliminating the need for cottonwood transplanting. Early invasion of vegetation at many of the burn sites has been dominated by jimson weed (Datura wrightii) and other native species. The sacatone grass (Sporobolus airoides) has responded favorably to the prescribed fire by expanding its cover to the banks of the wash that were previously shaded by tamarisk. The establishment of emergent plants such as cattail (Typha sp.) rushes (Juncus sp.) and sedges (Carex sp.) has also occurred due to the removal of tamarisk which competes for sunlight and water resources.

RESULTS

General Character of Daily Fluctuations

The general theory of diurnal fluctuation is that water consumption by plants during the day lowers the water table, while at night, when plants do not transpire, the water table rises because of inflow (recharge) to the aquifer. Examining graphs of water levels in the wells for three years indicated several patterns of fluctuation (Figure 5, 6 and 7). The most obvious are seasonal, daily and response to storm events.

During the March - October growing season, a prevalent daily pattern in all wells in the cut over stands of tamarisk indicated a general diurnal fluctuation of the water table. Amplitude and shape of daily oscillations are remarkably similar to each other and those published by White (1932). Because this pattern was seen in wells immediately adjacent to the stream channel, as well as those further away, daily fluctuation in stream flow was related to a similar, widespread fluctuation in the height

of the alluvial water table in the study area. The lowered water table during the day has the effect of less water to be discharged to the stream channel.

Water levels in all wells responded to most rainfall events by rapidly rising to a peak and receding relatively slowly to the pre-event level (Figure 5a and 6a). After major rainfall events, diurnal fluctuations were reduced until the recessional limb of the hydrograph approached the base flow, i.e. when water levels receded to approximately what existed before the storm event. At that point, daily fluctuations continued.

Fluctuations Produced by Different Types of Vegetation Cover

Changes in the amount and type of vegetation occurred throughout the study period. Most vegetation changes were due to climatic and seasonal effects, while other changes were due to the cutting and burning of the tamarisk stands and establishment of native species, all at different time periods. Hydrologic monitoring of these vegetative changes was complicated by the discontinuous record of water levels in the wells. Our study focuses on the comparison of fluctuations in one well (Well 3) in an untreated area to three other wells (Wells 1,2, and 4) in a treated area during the first year. During the second year, as well as the previous year, the three wells were observed to have similar responses as a group. The final year of the study documents a change that occurred among the wells from their previous responses. The original "untreated" well (Well 3) was not available for later comparisons due to equipment malfunction.

While most water levels in wells responded in parallel fashion, some differences are noticeable (Figures 8, 9, and 10). From June 4th to about June 14th 1992, water levels in Well 3, located in the heart of a tamarisk thicket before its removal in December, 1992, produced a short term, unique pattern not seen in other wells located in the cleared areas (Figure 8c). The amplitude of this pattern is 3 to 4 times greater than the prevalent fluctuations seen in the other wells during 1992 (Figure 8). Examining this pattern in detail

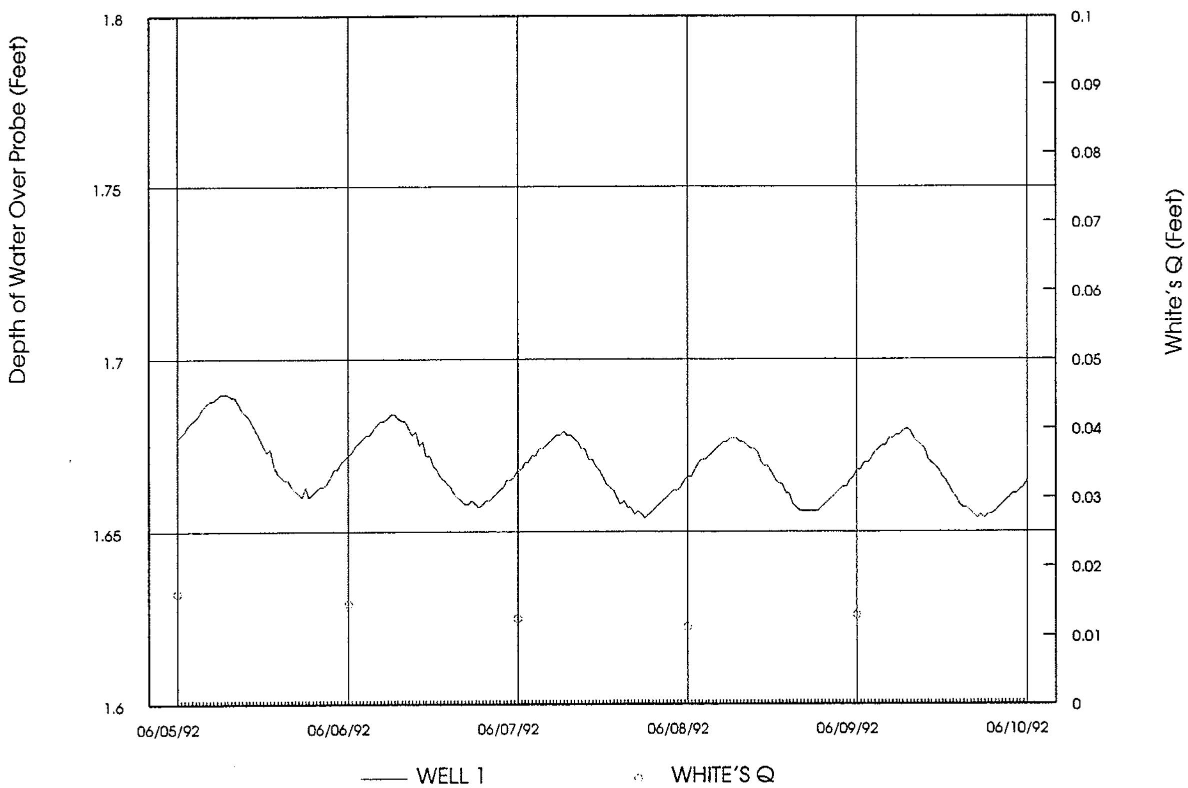


Figure 8a. Water Level Fluctuation in Well 1 in 1992

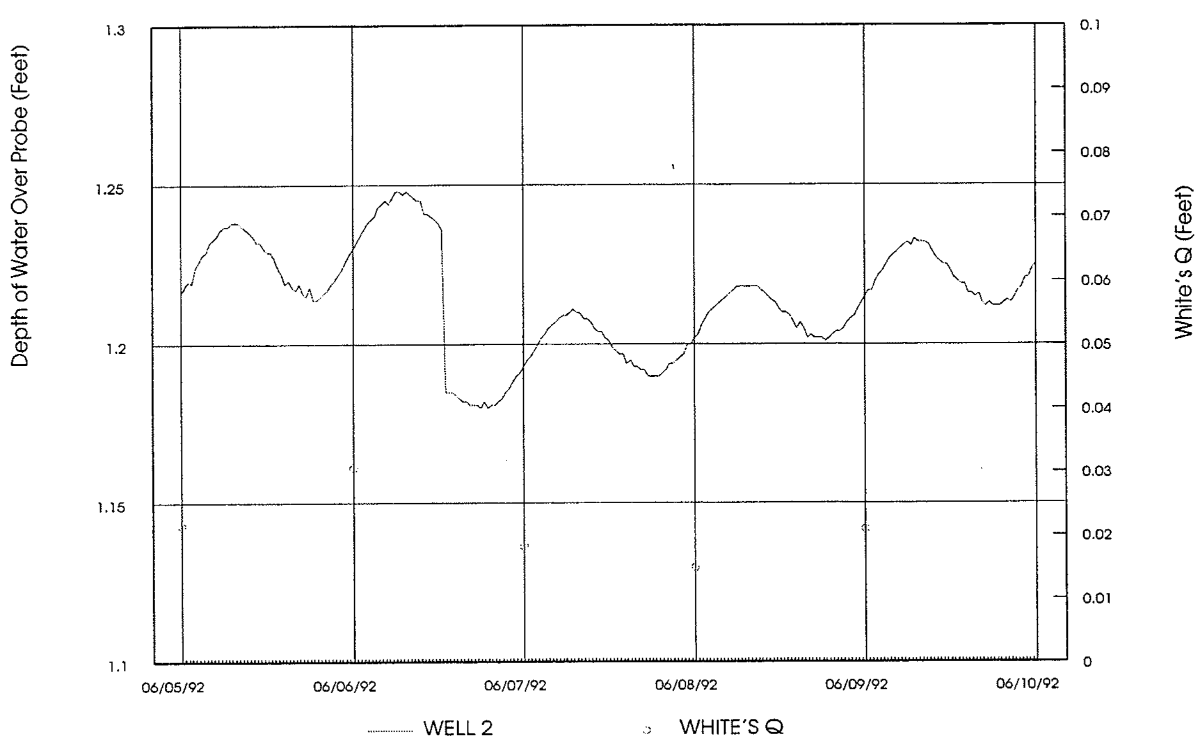


Figure 8b. Water Level Fluctuation in Well 2 in 1992

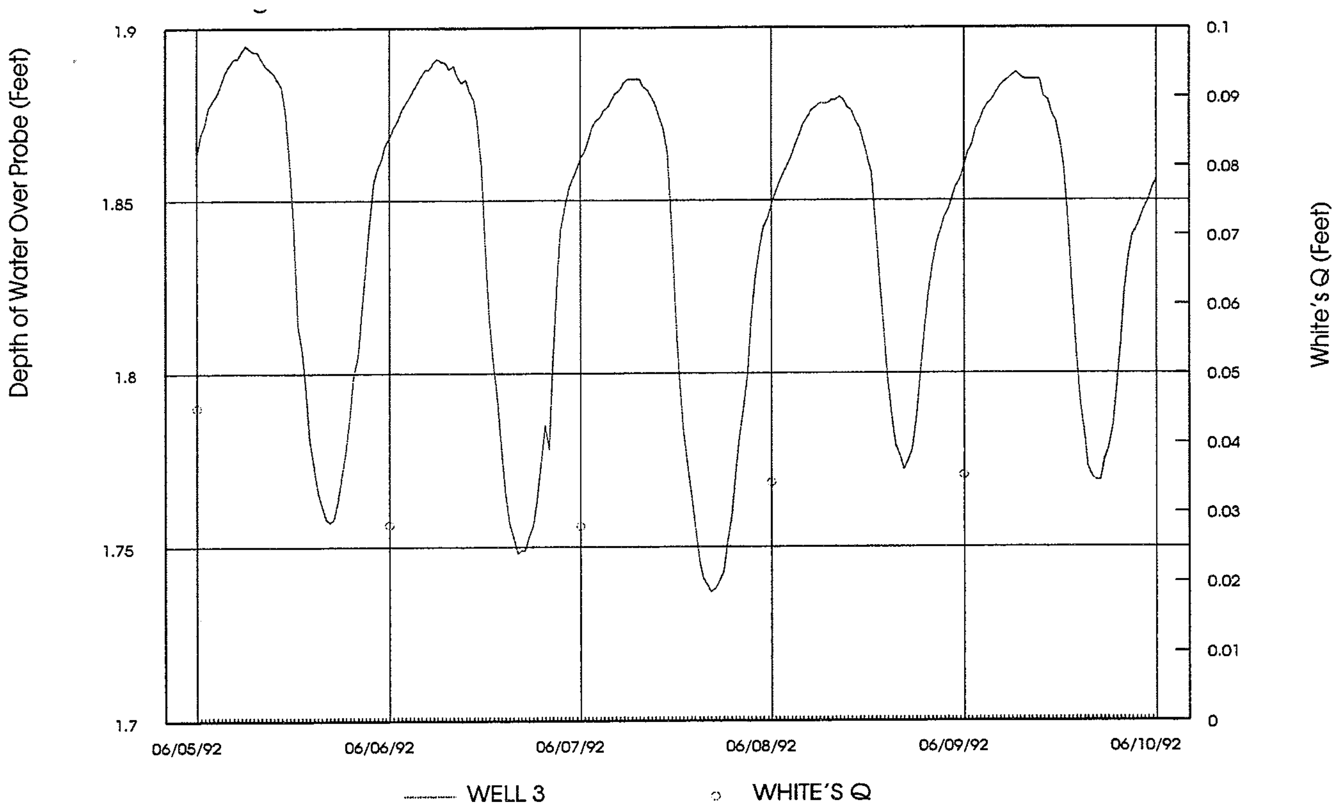


Figure 8c. Water Level Fluctuation in Well 3 in 1992

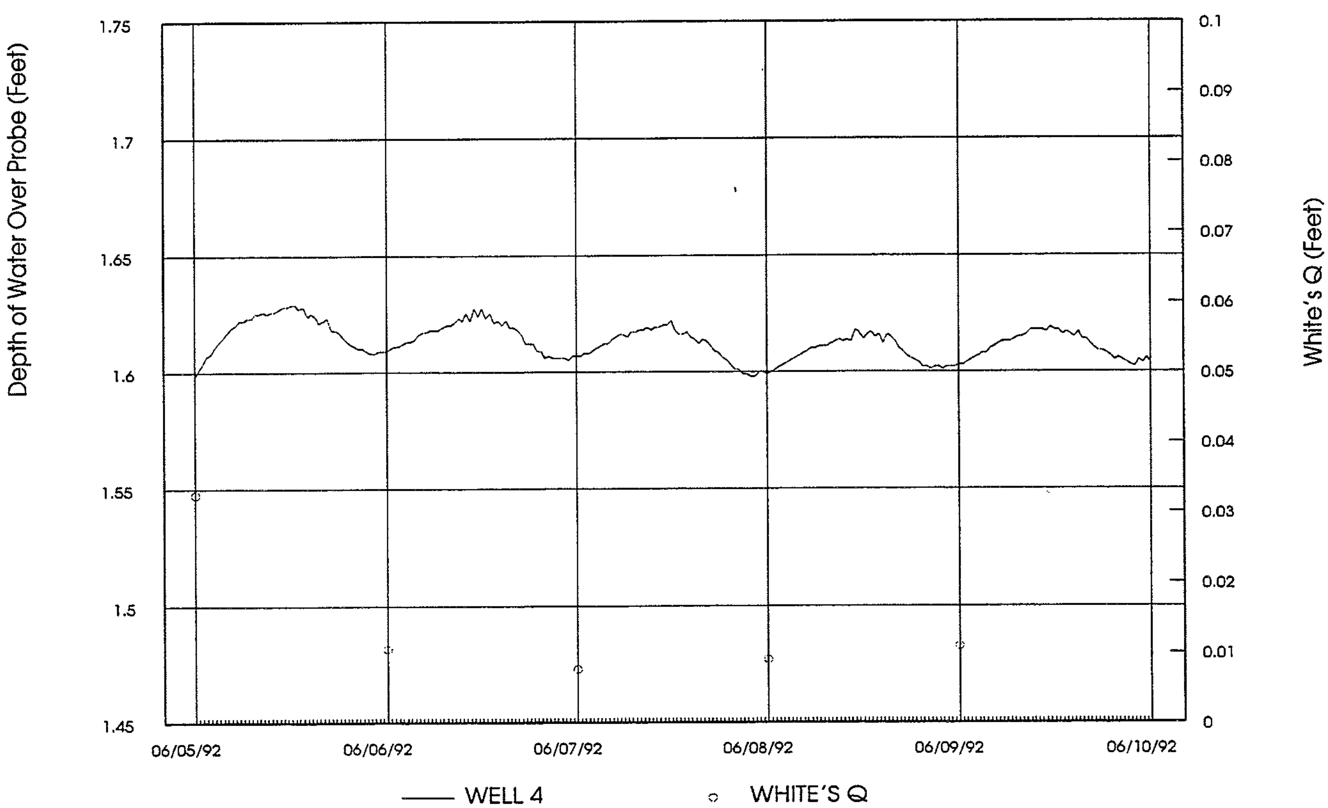


Figure 8d Water Level Fluctuation in Well 4 in 1992

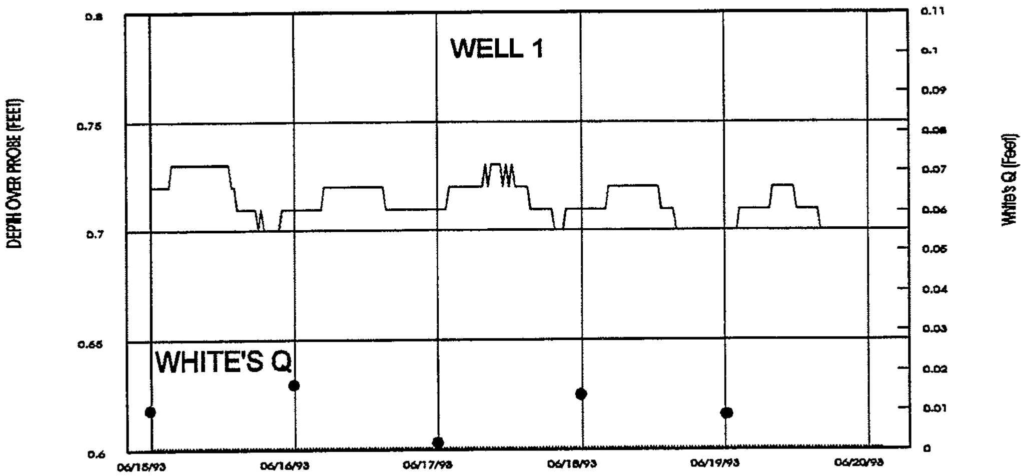


Figure 9a. Water Level Fluctuation in Well 1 in 1993

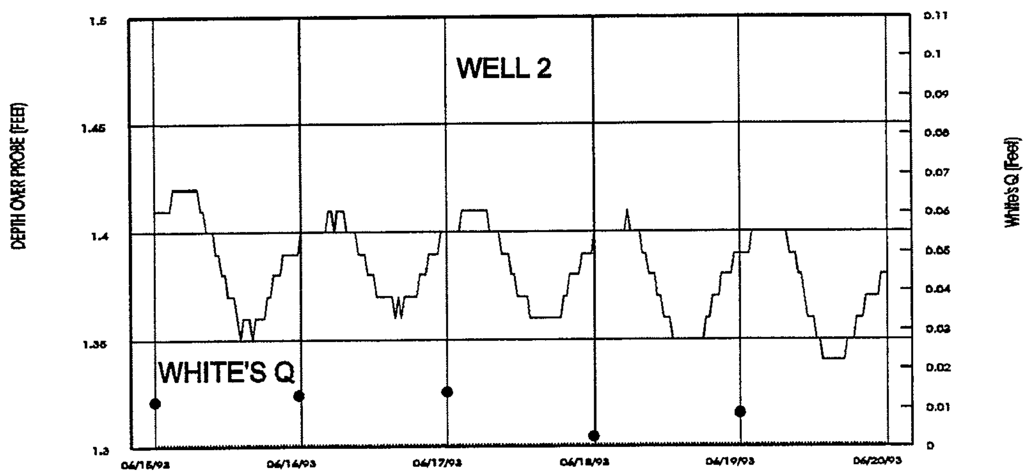


Figure 9b. Water Level Fluctuation in Well 2 in 1993

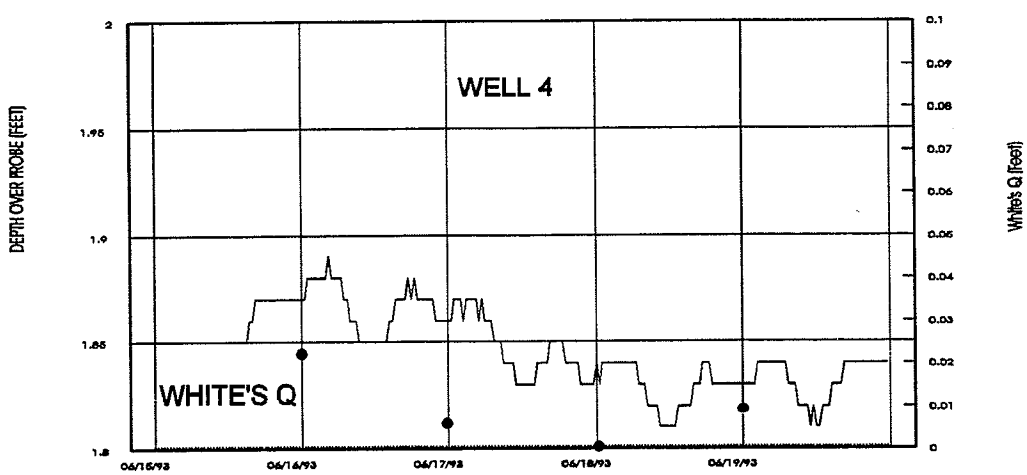


Figure 9c. Water Level Fluctuation in Well 4 in 1993

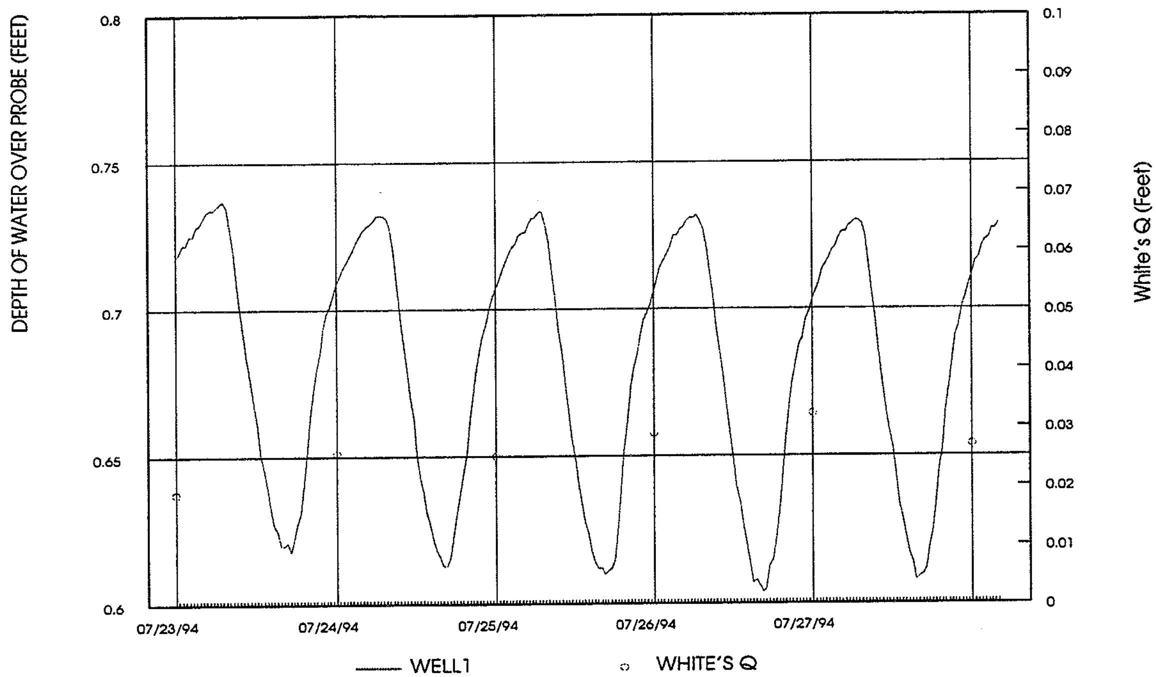


Figure 10a. Water Level Fluctuation in Well 1 in 1994

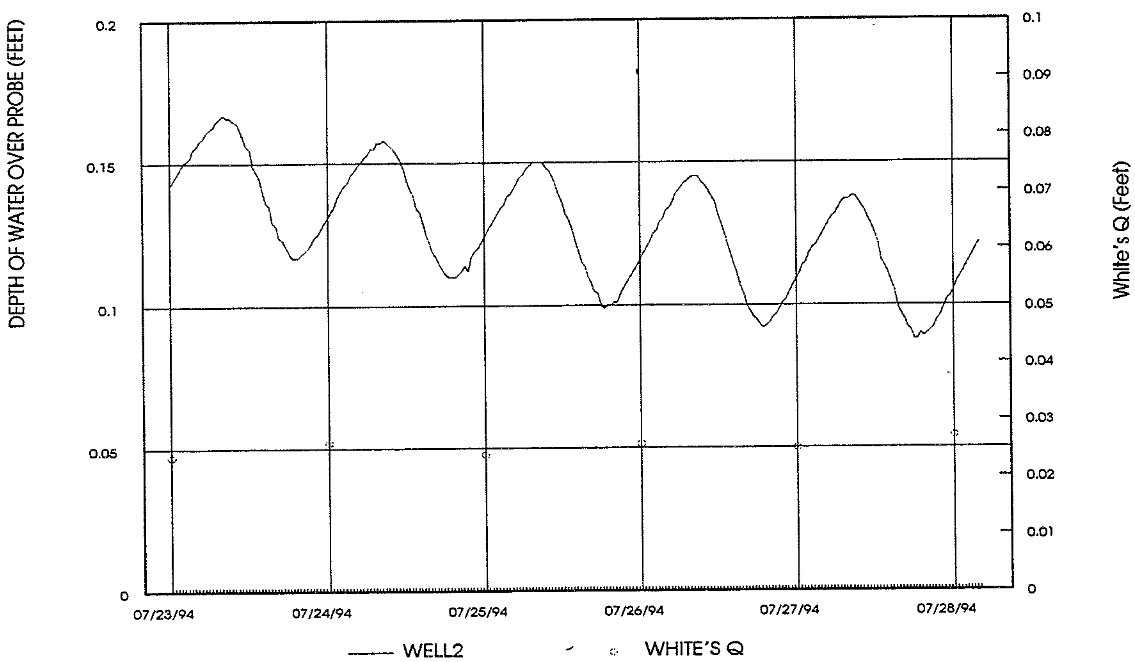


Figure 10b. Water Level Fluctuation in Well 2 in 1994

(Figure 8c) indicates the peaks of the fluctuations being about equal from day to day, while the level of depression varied. We interpret this unique fluctuation as localized drawdown of the water table by the tamarisk thicket during hot temperatures following abundant precipitation. The prevalent fluctuation in other wells is perceived as fluctuation related to diurnal changes in the cleared stands of tamarisk and to streamflow (source of recharge) which is responding to evapo-transpiration from other plant communities.

Wells 1 and 2 provided the most complete record of water fluctuation during the three years of hydrologic monitoring. For the first two years, water levels in these wells produced a pattern of fluctuation we identify as typical of cut-over tamarisk areas. In the third year, after reestablishment of native vegetation, large diurnal fluctuations were recorded for a short period.

In 1993 (Figure 9), water levels were recorded as a dataset with two significant digits (0.01 ft.) as opposed to three digits for other years. This unfortunate programming error affects the appearance of the graph and the precision of the results for that year.

This short period of water level fluctuations in Wells 1 and 2 in July, 1994 two years after the complete removal of tamarisk produced fluctuating patterns shown in Figures 10a and 10b. Well 2 water levels continue to fluctuate with background diurnal patterns believed to be related to stream flow reduction due to upstream evapotranspiration consumption. However, water level fluctuation in Well 1 was nearly as great as when tamarisk dominated Well 3. This implies that the re-established native vegetation has replaced the tamarisk in utilization of available alluvial water.

Fluctuations Due to Barometric Pressure and Temperature

A recording barometer and thermistor was added to the monitoring project during the second year to determine if the flow from Sacatone Spring is from a confined aquifer. Examination of the record did not indicate regular similarity of barometric pressure to water level fluctuations in the wells (Figure 11). However, a strong, inverse relationship to air temperature supports the premise that evapo-transpiration is driving the water level fluctuations. Indices of barometric pressure and temperature are used to plot the datum with water levels. Temperature was recorded as degrees celsius and divided by 100 for plotting. Barometric pressure (inches of Hq) was indexed by subtracting 26 from the recorded values.

Seasonal Fluctuation

Water levels in the wells showed a seasonal decline, particularly in the second year (Figure 6). The unusual rains in the first two years generated the "water table season," in that declines in the water table following each major rain event were similar to a normal annual cycle of a water table decline following a wet spring.

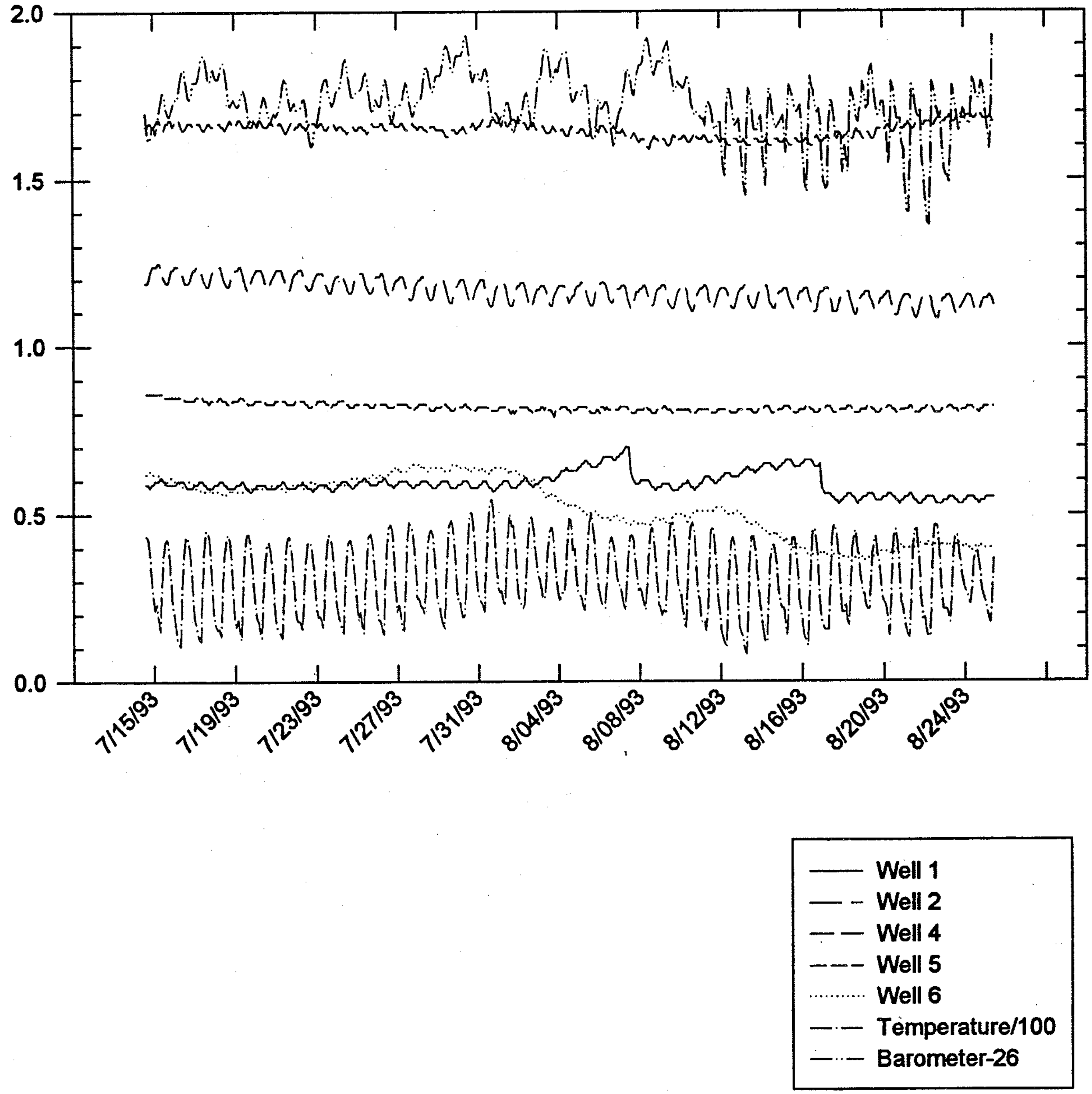


Figure 11. Fluctuation of Barometric Pressure, Air Temperature and Water Levels

Calculation of Water Consumption

Walter N. White (1932) described evapotranspiration processes in his paper and developed a formula to calculate water consumption based on water table fluctuations. An excerpt from his paper (pg 60) explains his theory:

> "During the day the capillary fringe is depleted by the plants, and the movement of ground water by capillary action to meet the depletion is more rapid than recharge by hydrostatic or artesian pressure. Therefore the water table declines and the head increases. During the night transpiration and evaporation losses are small, the water table moves upward, and the pressure head declines."
>
> "From about 6 to 10 in the evening and again from about 6 to 10 in the morning recharge approximately balances discharge, and for a few hours the water table is nearly at a standstill. This state of equilibrium would be reached earlier both in the evening and in the morning if it were not for lag in some of the operations. At or soon after sunset the rate of transpiration and evaporation declines to a small fraction of the rate that prevails during the day, but for a time the plants continue to draw some water to fill their circulatory systems, which have become somewhat depleted. (Nearly all plants become slightly wilted during the day, particularly on hot days, and tend to have a drooping appearance at night, quite in contrast with their fresh, turgid appearance in the morning.) Moreover, during the day the recharge of the capillary fringe from the zone of saturation lags somewhat behind the discharge by the plant action. By midnight, or slightly before, the veins of the plants have become filled with water. Meanwhile capillary equilibrium has been nearly established in the capillary fringe, and during the hours from midnight to morning there is little movement of water to the fringe from the zone of saturation."
>
> "Between midnight and 4 a.m. the water table is approximately at a mean elevation for the 24-hour period, and therefore the head is also approximately at a mean, provided there is no gain or loss in water-table elevation during the 24-hour period. If the water table has a net fall during the 24 hours, the head in the early morning hours mentioned is slightly above the noon to noon mean; and if it has a net rise, the head is slightly below the mean but the difference is generally not great. The velocity of water moving through a rock or soil varies approximately as the hydraulic gradient. Therefore if the slight losses by transpiration and evaporation between midnight and 4 a.m. are neglected, as well as the slight difference between the hydraulic head at this time and the true mean for the day, the hourly rate of recharge from midnight to 4 a.m. may be accepted as the average rate for the 24-hour period. The total quantity of ground water withdrawn by transpiration and evaporation during the 24-hour period can

then be determined by the formula

$$q=y(24r \pm s)$$

in which q is the depth of water withdrawn in inches, y is the specific yield of the soil in which the daily fluctuation of the water table takes place, r is the hourly rate of rise of the water table from midnight to 4 a.m. in inches, and s is the net fall or rise of the water table during the 24-hour period in inches. In field experiments the quantities on the right-hand side of the formula except the specific yield can be readily determined from the automatic records of water-table fluctuation".

White's (1932) formula was applied to water level fluctuations in wells during three periods of the study: within the remaining thicket around Well 3 when most of the stands had been cleared (1992), after the burn but before major growth of re-established natives (1993), and after native vegetation was fully established (1994).

Prior to applying the formula, the data set was checked for obviously erroneous values, time shifts, and probe drift. Selected five day periods of "clean" data were used for analysis in the study area (see Figs. 8, 9, and 10).

For the first period using White's (1932) methods and values for hourly rates of rise from four wells (Wells 1 and 2 are downstream and Well 3 in the Tamarisk thicket, Well 4 nearby and, Wells 5 and 6 were not operational) during the week of June 5, 1992 (Figures 8 and Table 3) and a specific yield of 25 percent, daily groundwater withdrawals due to evaporation and transpiration were calculated. The hourly rate of rise (r) between midnight

Well Name	Average Hourly Rise (r)	Average Difference Between Maximums (s)	Average Daily Consumption (q)[1]
Well 1	0.002 ft.	0.004 ft.	0.013 ft.
Well 2	0.003 ft.	0.015 ft.	0.021 ft.
Well 3	0.006 ft.	0.006 ft.	0.034 ft.
Well 4	0.002 ft.	0.003 ft.	0.014 ft.

[1] Where y = 25 % specific yield.

Table 3 Calculated Consumption from Four Wells on June 5-9, 1992.

and 4 a.m. was determined by averaging the four hours following midnight. The net rise or fall (s) was computed from the day to day differences between the highest peak, i.e. the difference between maximums from one day to the next.

Applying White's (1932) formula to the 1992 records from Wells 1, 2, 3, and 4 indicates that the quantity of water table consumption varies among the different wells. Well 3, based on the calculations and visually checked with the plotted data, consumed more than the other wells. Water level in the wells nearly recovered to previous levels at night. The average daily change of water levels among the wells are similar (except Well 2 which may be due to a recording anomaly), indicating a general consistency in the study area water table.

Table 4 and Figure 9 shows calculations from the recorded wells one year after the complete removal of tamarisk and the prescribed burn. In June 15-19, 1993, the amount of calculated water consumption is fairly uniform and not indicating much average change in the water table. This shows that evapotranspiration consumptions was greatly reduced in all areas.

Well Name	Average Hourly Rise (r)	Average Difference Between Maximums (s)	Average Daily Consumption (q)[1]
Well 1	0.002 ft.	0.006 ft.	0.010 ft.
Well 2	0.002 ft.	0.008 ft.	0.010 ft.
Well 4	0.002 ft.	0.010 ft.	0.011 ft.

[1] Where y = 25 % specific yield.

Table 4 Calculated Consumption for Three Wells June 15-19, 1993

For the third period when native plants were fully established, calculations for water level fluctuation measurements for July 23-28, 1994, (Table 5 and Figure 10) show an average consumption of 0.026 ft. and 0.025 for Well 1 and Well 2 respectively. This is comparable to results from Well 3 within the thicket of tamarisk before removal and Well 2 just downstream of the thicket prior to its removal.

Well Name	Average Hourly Rise (r)	Average Difference Between Maximums (s)	Average Daily Consumption (q)[1]
Well 1	0.004 ft.	0.003 ft.	0.026 ft.
Well 2	0.004 ft.	0.007 ft.	0.025 ft.

[1] Where y = 25 % specific yield.

Table 5 Calculated Consumption for Two Wells July 23-28, 1994

DISCUSSION

To estimate the annual amount of water consumption for a tamarisk stand using White's (1932) formula, discharge values should be calculated for each day of the year. This is because of the continually varying water level responses due to changing evapotranspiration driven by climate and moisture availability. The full record of Well 3 in the tamarisk thicket reveals that water level fluctuation did not continue on the same as June 5-9, 1992, therefore, q is not a representative value for all tamarisk in Table 3.

For improved estimates of water consumption, adjustments should be made to account for background fluctuation in stream flow. The relationship between stream stage and water levels in wells without the influence of vegetation and evaporation would need to be determined. Without accounting for stream stage fluctuation, calculated water consumption would likely decrease from wells adjacent to the stream channel.

Trends in Water Consumption by a Tamarisk Thicket Before and After Removal

Results of this study indicate that for short periods, the tamarisk thicket (Well 3) consumed larger amounts of water from the shallow aquifer compared to other monitoring locations. This trend varied over the 1992 growing season, with the largest differences in water table fluctuations occurring in early June and smaller divergences throughout the rest of 1992 as shown in Figure 5. After removal of the tamarisk (i.e., the 1993 growing season shown in Figure 6) such variation between wells did not appear; the wells fluctuated in a similar fashion. This suggests that removal of tamarisk had the anticipated effect -- water not used by plants is conserved in the aquifer (and discharged as streamflow) for longer periods during the growing season and is thus available for wildlife as well as native plants that do not have the drought tolerance of tamarisk.

Subsequent monitoring determined the response of the water table to replacement by native phreatophytes. The result is an increase in 1994 in consumption over the 1993 values, with the appearances of a return of the high values determined for the tamarisk thicket. Apparently the quantity of water consumed by the tamarisk thicket is exploited by a greater number of native phreatopytic species e.g., mesquite, cottonwood as shown in appendix C.

Transpiration Rates of Tamarisk vs. Native Vegetation

Evidence collected during this study indicates that large consumption of water by a thicket of tamarisk is variable. The largest fluctuations of the water table were observed under the thickest stands of tamarisk during a warm and sunny period after a runoff producing rainstorm. Sizable fluctuations, not as large as the first episode, were recorded in the same well later in the season during hot weather when runoff (stream flow) was still occurring. In all other wells that season and, in all wells after treatment the next year, large daily fluctuations were not seen. When native plants were successfully re-established, water consumption increased during the third year of the study and daily water table fluctuation patterns similar to those of the pre-treatment period were observed.

Effects of the Treatment

Vegetative Plot 5 (see Figure 3 for location) in the study area shows the most dramatic changes in vegetation. Comparing pretreatment to 2nd year data (see Appendix B) notice:

1) increase in plant diversity/composition from 8 to 19 species, 2) major increase in native species vs exotic (tamarisk), 3) tamarisk went from 64% of cover to 0%, and 4) increase in overall number of plants in the plot. The other plots reflect very similar results.

Water previously consumed by thickets of tamarisk is made available to native plants after tamarisk removal treatments. These plants utilized the newly available ground water when established in sites where tamarisk has been removed.

Applicability of White's Methods

Gatewood, et al. (1950) reviewed six methods for determining use of water by plants. Their review stated "The transpiration-well [White's] method would probably produce the most accurate results for the least amount of money, provided that the determinations of the coefficient of drainage [specific yield] were sufficiently accurate." The five other methods used in that study for determining water use by plants were: 1) tank method, 2) seepage-run method, 3) inflow-outflow method, 4) Chloride-increase method and, 5) slope-seepage method.

The present investigation at Sacatone Wash used the transpiration-well method because of the difficulties and\or inaccuracies of collecting data required for the other methods. White's method was applicable for conditions at Sacatone Wash because: 1) of the isolated water table aquifer generally not connected to regional ground water systems, 2) no other users of the ground water, and 3) surface water flow was irregular. Average daily water consumption near Well 3 (0.034 ft.) of this study for June 5-9, 1992 compares favorably to that reported for tamarisk (0.047 ft.) by Gatewood et al. (1950) for mean June tamarisk water consumption in Safford Valley, AZ.

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Appendix A

Sacatone Prescribed Burn
Report and Evaluation

1\5\93
Curt Deuser
Biological Technician
Prescribed Fire Manager
Sacatone Spring
Lake Mead National Recreation Area
National Park Service

Introduction:

The sacatone prescribed burn was conducted on November 30 through December 3, 1992. This inter-agency burn was completed according to the guidelines within the burn plan after over one year of planning. This report will summarize the daily events of the burn. Detailed fire behavior can be obtained with the fire monitoring report prepared by Paul Reeburg, Western Region Fire Office.

Burn Goals:

Create a fire that will consume as much of standing tamarisk thickets as possible. Tamarisk physiological characteristics were factors considering burning time of year. Tamarisk transpires at an extremely high rate, producing live fuel moisture samples during the summer of over 275%. Due to an expected lack of fire activity at these rates, tamarisk was burned during lower live fuel moisture levels, while it was preparing for dormancy just prior to leaf abscission. Mortality of the original shoot is the desired objective, which eliminates the labor intensive cutting process.

Daily Burn Events:

November 30:

Located and prepared water pools at the spring for setting up pumps and hoselays. Scouted areas where line improvements were needed and discussed holding and firing methods. Briefed crews about the need to prevent burning several native tree species adjacent to burn units.

December 1:

Completed ignition and burning of units 3,4,5 and partially of unit 6. Ignition began at 1130 and continued until 1430 with drip torches containing 60% diesel\40% unleaded gasoline.

Weather observations: Temp: mid 50's to mid 60's
Wind: 0-5mph
RH: 14%

The tamarisk trees in units 3 and 5 did not burn thoroughly due to a lack of ground fuels within the thicket. (A flood in March 1992 washed away much of the ground fuels that previously existed.) The sacatone grass (Sporobolis airoides) with green leaf blades, burned very well. A large tamarisk tree, 20 feet tall, in unit 6 burned
thoroughly, leaving only a skeleton. This intensity was due to

the large amount of fuels around the base including grasses, shrubs, and tamarisk branches.

<u>December 2</u>:

Completed units 1 and 2. A weather change occurred with a front moving in causing overcast skies.

Weather Observations: Temp: 58 degrees F.
Wind: 0-3mph
RH: 22-16%

Unit 2 was ignited with drip torches at 1130, this unit contained large amounts of cured tamarisk and arroweed slash that burned intensely producing extreme heat. A few green tamarisk were thoroughly burned due to slash piles around bases. Adjacent native trees obtained slight heat scorching and were protected by one inch hose line. A fire effects grass monitoring plot was established and ignited separately within unit 2. Ignition of this grass was by a single strip of fire on the south side using a drip torch. The fire was then carried naturally with the help of a slight wind from the south.

Unit 1 was ignited at 1400 with the use of a terra torch flame thrower, with drip torches used to fire the far ends. Due to cool weather the terra torch fuel did not gel properly which decreased the torch's range. Direct flame from the terra torch was required to consume the green tamarisk successfully. This truck mounted terra torch was only used at this unit due to accessibility limitations.

<u>December 3</u>:

Units 7 and 4 were completed including mop up and breaking down and pulling out all fire related equipment.

Weather Observations: A front had arrived creating a 90% cloud cover with rain threatening.
Temp: 52-55 F.
Wind: 0-2 mph
RH: 32-21%

Unit 7 consisted of lighting individual tamarisk trees due to non continuous fuels. We experimented with the use of blivet bags as an additional ignition and heat source. The blivet bags consisted of 1 gallon size ziplock plastic storage bags filled with a half gallon of terra torch fuel. The bags were placed at the base of the tamarisk trees and drip torches were used to light ground litter near the bags. When the bags ignited, the fire intensity increased sufficiently to sustain combustion in the base of the trees and also caused partial torching. This increased fire behavior is desired in order to consume much of the base and to kill the shoot.

The increased fire intensity lasted less than ten minutes due to the poor fire weather experienced on this day. This method is very promising and should be experimented on a day with more

adverse fire conditions.
Unit 4 consisted of several small slash piles that were ignited with drip torches. The slash burned completely but some green tamarisk trees that had slash at the base were scorched but not consumed.

Evaluation:

The overall conclusion is that tamarisk is extremely challenging to burn under the conditions experienced. However, we found that it is capable of burning with dense ground fuels built around the base. High intensity fires are needed to sustain combustion of tamarisk trees. The presence of surface water at this intermittent stream may have decreased the fire behavior by increasing the relative humidity within the tamarisk canopy lining the stream banks. The spring is usually dry during this period of the year.
The burn was successful in removing all tamarisk slash and some live trees were consumed. Monitoring tamarisk trees during the sprouting period this spring will be crucial to determine what burn severity is needed to kill the shoots. Resprouting is expected to occur at the root crowns of most trees regardless if the shoot has been killed. Herbicides will be applied to these small resprouts. The use of blivet bags was successful and should be considered for use in future burns. Better burning success would have been achieved if blivet bags were used in firing units 3 and 4. The remaining un-burned tamarisk will be cut and slash piled for burning after a curing period.
There were two dominate native species that were included within most of the burn units. The shrub Baccharis sergiloides burned readily and was responsive to sustaining fire even with green stems and leaves. Sacatone grass was also very responsive to fire while partially green and with moisture at the base of the clumps. A mature stand of this grass was ignited in unit 3 that contained a fire effects monitoring grass plot that was recorded by fire monitors. (Refer to the fire monitoring report by Paul Reeburg for detailed fire behavior data of this grass plot.) Charred clumps of the sacatone remain which should stimulate a lush regrowth this spring. Monitoring the recovery of this stand will be documented to determine the sacatone re-establishment while competing with the exotic Bromus rubens.
This multi agency prescribed fire crew included members from the Bureau of Land Management, Nevada Division of Forestry, and rangers, interpreters, and resource managers from Lake Mead NRA. We maintained complete control of all fires with no escapes or spots. Line construction was kept to a minimum while taking advantage of natural barriers and using wet lines for holding.
The fire fighting crew consisted of 10-14 persons with no injuries incurred during this four day prescribed burn.

Recommendations for future tamarisk RX burns:

1. Burn during extreme fire weather to increase fire consumption of tamarisk. This may include burning during high live fuel moisture levels. This can be accomplished with only minor control problems if carefully planned due to the proximity of tamarisk thickets and lack of adjacent fuels.

2. Additional slash, 10 hour to 1000 hour fuels, may need to be placed at the bases of some trees to increase fire intensity and sustain flaming of tamarisk. Cutting of some tamarisk trees to create more slash may be required in areas lacking ground fuels.

3. Conduct burn without surface water present at intermittent springs. This will reduce the moist micro-climate within the tamarisk stands.

4. Blivet bags are excellent ignition devises to increase the fire intensity and should be used when fuels are sparse.

*Note: This burn is part of a multi-faceted experimental spring restoration project including water table monitoring, tamarisk eradication techniques and revegetation with native plants.

Equipment used to conduct burn:

Fire Engine
Mark 26 pump
Mini pump
400 ft. of 1.5 inch hose
500 ft. of 1 inch hose
6 drip torches
truck mounted terra torch with fuel
chainsaw
15 hand tools
25 gallons of drip torch fuel
2 fedcos
fusees
belt weather kit
hand held radios
2 burn signs
binoculars
video camera
35mm camera

Burn Organization:

Prescribed Fire Manager	Curt Deuser, NPS
Prescribed Burn Boss	Jim McCray, BLM
Fire Behavior Analyst	Rob Rufferidge, NDF
Safety Officer/EMT	NPS Ranger
Lookout	Joe Wegener, NPS
Ignition Specialists	NPS, BLM, NDF personnel
Holding Specialists	NPS, BLM personnel
Lead Fire Behavior and Weather Specialist	Paul Reeburg, NPS
Cultural Resource Advisor	Leslie Peterson, NPS
Engine Operator	Ed O'Sullivan, BLM
Pump Operator	Henry Ramirez, BLM
Photographers	Leslie DeBauchamp, Bill Burke, NPS

Appendix B - Brush Transect Vegetation Frequency and Relative Cover Data from unpublished data on file at the Natural Resources Division, Lake Mead NRA, Boulder City, NV.

FMH   Fire Monitoring Handbook Data Analysis - LAME   11/10/94
Brush Transect Vegetation Frequency and Relative Cover

List of menu selections for this output:
- Live perennials & all annuals, lump others
- By species
- Burn plots
- Preburn (most recent)
- Select from list of monitoring types
- Select from a list of individual plots

List of plots output:

Indexcode	Stat	Plot
BTARA1D06	PRE	2
BTARA1D06	PRE	3
BTARA1D06	PRE	5

---------------[Type:BTARA1D06 Plot: 2 B/C:B Stat:PRE]---------------

#	SPECIES	NATIVE	% FREQ	% AS TALLEST	% COVER
1	Sporobolus airoides	Y	45.00	30.00	40.54
2	Bromus madritensis.	N	32.00	8.00	28.83
3	Tamarix ramosissima	N	27.00	27.00	24.32
4	Dead perennials	-	25.00	21.00	-
5	Non-plant	-	12.00	12.00	-
6	Baccharis sergiloides	Y	2.00	1.00	1.80
7	Polypogon monspeliensis	N	2.00	1.00	1.80
8	Erodium cicutarium.	N	1.00	0.00	0.90
9	Juncus bufonius	Y	1.00	0.00	0.90
10	Stillingia linearifolia	Y	1.00	0.00	0.90

Total # points = 100, Avg. species/point = 1.5, Avg. height = 0.087m
Nat. species = 49 of 111 plants (44.1%)

---------------[Type:BTARA1D06 Plot: 3 B/C:B Stat:PRE]---------------

#	SPECIES	NATIVE	% FREQ	% AS TALLEST	% COVER
1	Tamarix ramosissima	N	51.00	50.00	35.42
2	Sporobolus airoides	Y	43.00	26.00	29.86
3	Bromus madritensis.	N	34.00	6.00	23.61
4	Dead perennials	-	14.00	9.00	-
5	Polypogon monspeliensis	N	13.00	1.00	9.03
6	Non-plant	-	6.00	6.00	-
7	Pluchea sericea	Y	2.00	1.00	1.39
8	Larrea tridentata	Y	1.00	1.00	0.69

Total # points = 100, Avg. species/point = 1.6, Avg. height = 0.115m
Nat. species = 46 of 144 plants (31.9%)

---------------[Type:BTARA1D06 Plot: 5 B/C:B Stat:PRE]---------------

#	SPECIES	NATIVE	% FREQ	% AS TALLEST	% COVER
1	Tamarix ramosissima	N	84.00	83.00	63.64
2	Dead perennials	-	23.00	11.00	-
3	Sporobolus airoides	Y	20.00	2.00	15.15
4	Polypogon monspeliensis	N	16.00	1.00	12.12

5	Bromus madritensis.	N	10.00	2.00	7.58
6	Lycium andersonii	Y	1.00	0.00	0.76
7	Non-plant	-	1.00	1.00	-
8	Sonchus asper	N	1.00	0.00	0.76

Total # points = 100, Avg. species/point = 1.6, Avg. height = 0.275m
Nat. species = 21 of 132 plants (15.9%)

End of file

FMH Fire Monitoring Handbook Data Analysis - LAME 11/10/94

Brush Transect Vegetation Frequency and Relative Cover

List of menu selections for this output:
Live perennials & all annuals, lump others
By species
Burn plots
Postburn (month or year)
Select from list of monitoring types
Select from a list of individual plots

List of plots output:

Indexcode	Stat	Plot
BTARA1D06	yr01	2
BTARA1D06	yr01	3
BTARA1D06	yr01	5

---------------[Type:BTARA1D06 Plot: 2 B/C:B Stat:yr01]---------------

#	SPECIES	NATIVE	% FREQ	% AS TALLEST	% COVER
1	Sporobolus airoides	Y	78.00	77.00	56.12
2	Lythrum californicum	Y	14.00	4.00	10.07
3	Bromus madritensis	N	10.00	1.00	7.19
4	Typha angustifolia	Y	10.00	6.00	7.19
5	Non-plant	-	9.00	9.00	-
6	Mimulus pilosus	Y	6.00	0.00	4.32
7	Polypogon monspeliensis	N	4.00	0.00	2.88
8	Agrostis species uncertain	N	3.00	2.00	2.16
9	Conyza canadensis	N	3.00	0.00	2.16
10	Unknown Grass species	N	2.00	0.00	1.44
11	Juncus species unknown	Y	2.00	0.00	1.44
12	Algae	N	1.00	1.00	0.72
13	Artemisia ludovichiana	Y	1.00	0.00	0.72
14	Baccharis sergiloides	Y	1.00	0.00	0.72
15	Carex species uncertain	N	1.00	0.00	0.72
16	Datura wrightii	Y	1.00	0.00	0.72
17	Dead perennials	-	1.00	0.00	-
18	Lactuca serriola	N	1.00	0.00	0.72
19	Sonchus asper	N	1.00	0.00	0.72

Total # points = 100, Avg. species/point = 1.5, Avg. height = 0.066m
Nat. species = 113 of 139 plants (81.3%)

---------------[Type:BTARA1D06 Plot: 3 B/C:B Stat:yr01]---------------

#	SPECIES	NATIVE	% FREQ	% AS TALLEST	% COVER
1	Sporobolus airoides	Y	46.00	46.00	58.97
2	Non-plant	-	36.00	36.00	-
3	Dead perennials	-	10.00	8.00	-
4	Bromus madritensis	N	6.00	0.00	7.69
5	Mimulus pilosus	Y	5.00	2.00	6.41
6	Erodium cicutarium	N	4.00	0.00	5.13
7	Pluchea sericea	Y	4.00	4.00	5.13
8	Polypogon monspeliensis	N	4.00	0.00	5.13
9	Unknown Grass species	N	3.00	1.00	3.85
10	Algae	N	2.00	2.00	2.56
11	Sonchus asper	N	2.00	0.00	2.56

12	Gnaphalium stramineum	Y	1.00	0.00	1.28
13	Typha angustifolia.	Y	1.00	1.00	1.28

Total # points = 100, Avg. species/point = 1.2, Avg. height = 0.033m
Nat. species = 57 of 78 plants (73.1%)

---------------[Type:BTARA1D06 Plot: 5 B/C:B Stat:yr01]---------------

#	SPECIES	NATIVE	% FREQ	% AS TALLEST	% COVER
1	Non-plant	-	37.00	37.00	-
2	Sporobolus airoides	Y	30.00	30.00	29.13
3	Polypogon monspeliensis	N	16.00	8.00	15.53
4	Agrostis species uncertain.	N	13.00	3.00	12.62
5	Bromus madritensis.	N	9.00	1.00	8.74
6	Datura wrightii	Y	9.00	7.00	8.74
7	Mimulus pilosus	Y	9.00	2.00	8.74
8	Dead perennials	-	8.00	7.00	-
9	Baccharis sergiloides	Y	7.00	1.00	6.80
10	Artemisia ludovichiana.	Y	3.00	2.00	2.91
11	Lythrum californicum.	Y	3.00	0.00	2.91
12	Algae	N	2.00	2.00	1.94
13	Mimulus guttatus.	N	1.00	0.00	0.97
14	Sonchus asper	N	1.00	0.00	0.97

Total # points = 100, Avg. species/point = 1.5, Avg. height = 0.028m
Nat. species = 61 of 103 plants (59.2%)

End of file

Brush Transect Vegetation Frequency and Relative Cover

List of menu selections for this output:
- Live perennials & all annuals, lump others
- By species
- Burn plots
- Postburn (month or year)
- Select from list of monitoring types
- Select from a list of individual plots

List of plots output:

Indexcode	Stat	Plot
BTARA1D06	yr02	2
BTARA1D06	yr02	3
BTARA1D06	yr02	5

---------------[Type:BTARA1D06 Plot: 2 B/C:B Stat:yr02]---------------

#	SPECIES	NATIVE	% FREQ	% AS TALLEST	% COVER
1	Sporobolus airoides	Y	86.00	69.00	58.90
2	Lythrum californicum.	Y	14.00	5.00	9.59
3	Baccharis sergiloides	Y	8.00	6.00	5.48
4	Datura wrightii	Y	7.00	5.00	4.79
5	Polypogon monspeliensis	N	7.00	4.00	4.79
6	Typha angustifolia.	Y	7.00	6.00	4.79
7	Artemisia ludovichiana.	Y	3.00	2.00	2.05
8	Bromus madritensis.	N	3.00	0.00	2.05
9	Acacia greggii.	Y	2.00	1.00	1.37
10	Juncus species unknown.	Y	2.00	1.00	1.37
11	Nicotiana obtusifolia	Y	2.00	1.00	1.37
12	Centaurium calycosum.	Y	1.00	0.00	0.68
13	Conyza canadensis	N	1.00	0.00	0.68
14	Dead perennials	-	1.00	0.00	-
15	Juncus species unknown.	Y	1.00	0.00	0.68
16	Lactuca serriola.	N	1.00	0.00	0.68
17	Mimulus cardinalis.	Y	1.00	0.00	0.68

Total # points = 100, Avg. species/point = 1.5, Avg. height = 0.105m
Nat. species = 134 of 146 plants (91.8%)

---------------[Type:BTARA1D06 Plot: 3 B/C:B Stat:yr02]---------------

#	SPECIES	NATIVE	% FREQ	% AS TALLEST	% COVER
1	Sporobolus airoides	Y	61.00	55.00	57.01
2	Non-plant	-	17.00	15.00	-
3	Datura wrightii	Y	12.00	12.00	11.21
4	Bromus madritensis.	N	9.00	3.00	8.41
5	Muhlenbergia porteri.	Y	8.00	4.00	7.48
6	Polypogon monspeliensis	N	8.00	5.00	7.48
7	Dead perennials	-	2.00	2.00	-
8	Erodium cicutarium.	N	2.00	0.00	1.87
9	Pluchea sericea	Y	2.00	2.00	1.87
10	Centaurium calycosum.	Y	1.00	1.00	0.93
11	Gnaphalium stramineum	Y	1.00	1.00	0.93
12	Juncus species unknown.	Y	1.00	0.00	0.93
13	Mimulus guttatus.	N	1.00	0.00	0.93

14	Vulpia octoflora.	Y	1.00	0.00	0.93

Total # points = 100, Avg. species/point = 1.3, Avg. height = 0.066m
Nat. species = 87 of 107 plants (81.3%)

---------------[Type:BTARA1D06 Plot: 5 B/C:B Stat:yr02]---------------

#	SPECIES	NATIVE	% FREQ	% AS TALLEST	% COVER
1	Sporobolus airoides	Y	40.00	30.00	22.86
2	Lythrum californicum.	Y	34.00	17.00	19.43
3	Polypogon monspeliensis	N	28.00	12.00	16.00
4	Datura wrightii	Y	20.00	17.00	11.43
5	Bromus madritensis.	N	10.00	3.00	5.71
6	Artemisia ludovichiana.	Y	9.00	6.00	5.14
7	Gnaphalium stramineum	Y	8.00	0.00	4.57
8	Baccharis sergiloides	Y	6.00	1.00	3.43
9	Dead perennials	-	5.00	3.00	-
10	Non-plant	-	5.00	5.00	-
11	Mimulus cardinalis.	Y	4.00	0.00	2.29
12	Chloris virgata	N	3.00	1.00	1.71
13	Muhlenbergia porteri.	Y	3.00	0.00	1.71
14	Centaurium calycosum.	Y	2.00	1.00	1.14
15	Cynodon dactylon.	N	2.00	1.00	1.14
16	Sarcostemma hirtellum	Y	2.00	0.00	1.14
17	Typha angustifolia.	Y	2.00	2.00	1.14
18	Juncus species unknown.	Y	1.00	0.00	0.57
19	Sonchus asper	N	1.00	1.00	0.57

Total # points = 100, Avg. species/point = 1.9, Avg. height = 0.093m
Nat. species = 131 of 175 plants (74.9%)

End of file

Appendix C - Summary of preburn, one-year postburn and two-year postburn data collected on fire effects transects in Sacatone Wash from Taylor, J. 1994. NPS fire Effects Monitoring Report.

APPENDIX C. **Summary of preburn, one-year postburn and two-year postburn data collected on fire effects transects in Sacatone Wash**

Introduction

A total of nine fire effects transects are located in Sacatone Wash. Eight of the nine transects (referred to as TARA transects) are located in the center of the wash where once dense thickets of tamarisk grew. One grass transect (referred to as the SPAI transect) is located in a small grassy meadow on the north side of the wash. The area was burned during a prescribed burn conducted in December of 1992. In addition to being burned, the tamarisk has been manually removed and treated with herbicide. The manual removal and the herbicide treatment are primarily responsible for the decrease of tamarisk in the wash.

On most of the transects only small portions of the transect burned (see attached burn severity measurements), therefore, the data collected may not truly show "fire effects", however, the data collected does show what changes in species composition are taking place as a result of removing the tamarisk.

Attached are four sets of graphs:

1. Frequency, relative cover and brush density on the one SPAI transect (Figures 1, 2, 3)

2. Frequency and relative cover of ***grass*** species on the TARA transects (Figures 4, 5)

3. Frequency and relative cover of ***brush*** species on the TARA transects (Figures 6, 7)

4. Brush density of individual brush species on the TARA transects (Figures 8, 9, 10, 11)

Below is discussed the changes in frequency and relative cover of the dominant grass and brush species in the one grassland plot and the eight tamarisk plots.

Since the terms frequency and relative cover will be used frequently in the discussion that follows they are defined below.

Frequency: the number of times a species is hit on a transect divided by the total number of sample points

Relative cover: the portion of ground covered by a species compared with the overall plant cover

Changes in Frequency and Relative Cover of selected grass species

In the one SPAI transect the overall species diversity was low with Sacaton (*Sporobolus airoides*) being the dominant species followed by Red Brome (*Bromus madritensis* ssp. *rubens*). Occasional hits of other grasses as well as native and non-native forbs were encountered on the transect. Sacaton is a perennial bunch grass which produces large tussocks of basal leaves which form almost a continuous ground cover. One-year postburn, Sacaton showed a decrease in frequency and relative cover. The decrease of Sacaton is due to the reduction in the size of the basal tussock of leaves by the fire. Two years postburn, Sacaton recovered nearly to its preburn frequency and cover having had time to regrow its basal leaves (Fig. 1).

The second most common grass species, Red Brome, a non-native annual grass species, showed a slight decrease in frequency one year postburn. Two years postburn, frequency of Red Brome increased beyond its preburn frequency though not dramatically. Though the increase was not dramatic it is worth noting since Red Brome is a widespread weed.

In contrast to the SPAI transect, in the TARA transects, Sacaton showed an increase in frequency both one and two years postburn and Red Brome decreased in frequency (Fig. 4). Whereas Red Brome may have been better able to grow under the dense canopy of the tamarisk, once the tamarisk was removed the Sacaton was able to expand. With the removal of the tamarisk a second non-native grass, Rabbitfoot grass (*Polypogon monspeliensis)* has also increased in frequency though not significantly (Fig. 4). Like Red Brome, Rabbitfoot grass is a weedy grass and it is important to monitor changes in its frequency and relative cover.

Changes in Frequency and Relative Cover of selected brush species

In Figures 6 and 7 are graphed the frequencies and relative covers of six brush species found on the eight TARA transects. The species graphed have been selected because they were either the dominant species preburn or are increasing in cover and density postburn. California Loosestrife (*Lythrum californicum)* and Indian Apple (*Datura wrightii*) are more sub-shrubs in habit but have been included since they have notably increased in frequency and relative cover each year postburn.

Tamarisk (*Tamarix ramosissima*), the species targeted for removal and which dominated the brush cover preburn has decreased in cover from 40% preburn to 0.1% two-years postburn (Fig. 7). The presence of live tamarisk in years one and two is due to resprouting tamarisk shrubs. Though some tamarisk did resprout, it was only a small percentage of preburn matures that did so (Fig. 8).

Arrow weed (*Pluchea sericea*), Silver worm wood (*Artemisia ludovichiana*), California loosestrife and Indian apple all showed an increase in frequency and relative cover both one and two years postburn. The increase in frequency and relative cover reflect the increase in brush density of each of these shrub species (Fig. 10, 11). Graphs of brush density are not included for California loosestrife and Indian apple since they are not truly shrub species and therefore brush density data was not collected for these two species.

Arrow weed, which has increased in both frequency, relative cover and density, appears to be the most rapidly expanding shrub species in the wash forming dense thickets in intermittent patches along the length of the wash.

Perhaps the most notable change in the presence of Desert Baccharis (*Baccharis sergiloides*) was found in the one SPAI transect. Whereas no Desert Baccharis was found preburn nor one-year postburn, it has begun to populate the grassland two-years postburn (Fig. 3).

Summary

In June of 1994 when the two-year postburn monitoring was conducted, water flowed through the wash and several new species of rushes and sedges were found growing. Centaury (*Centaurium calycosum*), Scarlet monkey-flower (*Mimulus cardinalis*) and Indian apple were in full bloom. Sacaton grew dense in some areas with individual tussocks measuring one to two feet in diameter. The overall impression of the area was one of a healthy desert wash.

With the removal of the tamarisk, Sacatone wash has been been converted from a tamarisk thicket to a wash where there is a high diversity of forbs, shrubs, grasses, sedges and rushes. Native species composition has increased in each monitoring year as follows:

	Year	% Native
(Preburn)	1991	38.1%
(YR01)	1993	71.5%
(YR02)	1994	82.9%

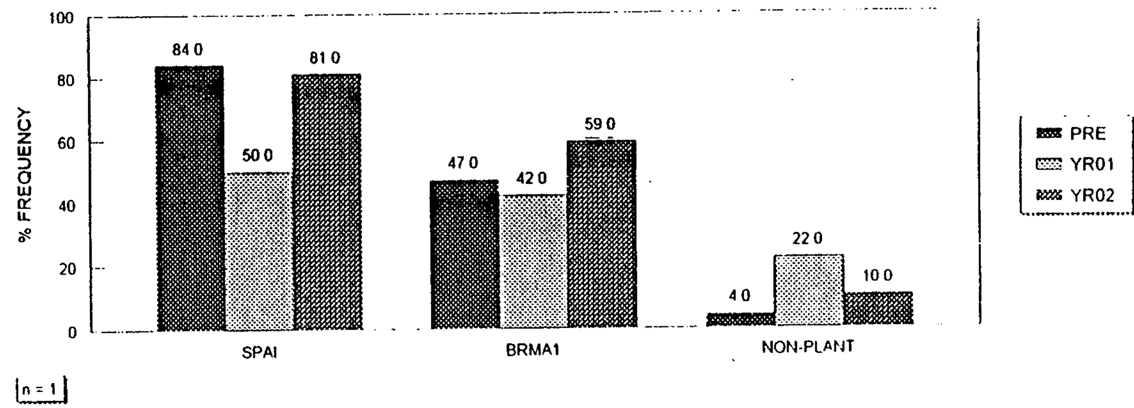
Though none were encountered on the transects nor recorded in the brush belt, several tamarisk seedlings were found and pulled while walking through the wash. This indicates that tamarisk seed still lies in the seed bank and that it will take continued diligence in removing tamarisk seedlings to insure that tamarisk does not once again dominate the wash.

Five-year postburn monitoring of the nine transects located in Sacatone wash will be conducted in 1997. Whereas the one and two-year postburn monitoring gave a short range look at the changes in species composition, the five-year postburn monitoring will give a longer range look. The data may show that tamarisk has begun to reestablish itself or that native species have continued to expand and dominate the vegetative composition of the wash.

COMPARISON OF PREBURN AND POSTBURN DATA FROM SACATON GRASS TRANSECT, BSPAI1D01 01

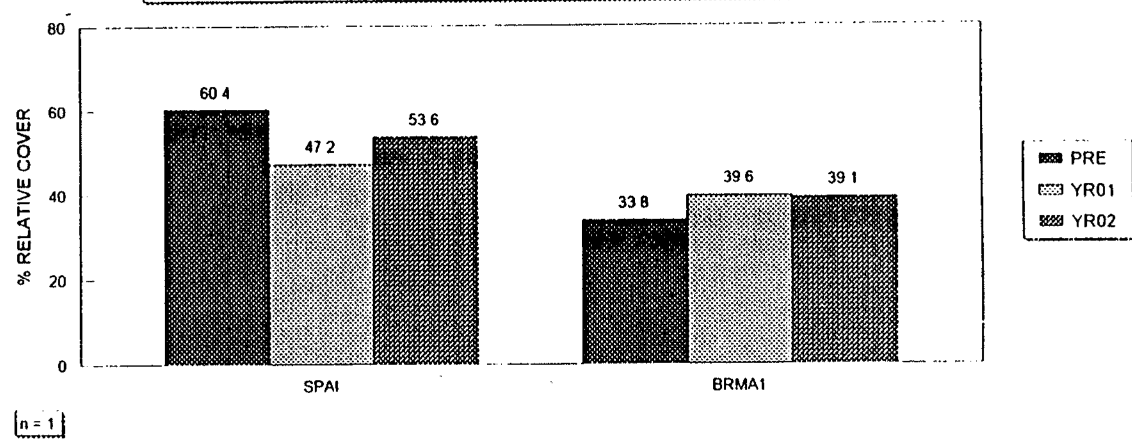
SPECIES CODE	% FREQUENCY PRE	YR01	YR02
SPAI	84.0	50.0	81.0
BRMA1	47.0	42.0	59.0
NON-PLANT	4.0	22.0	10.0

FIGURE 1. % FREQUENCY OF TWO DOMINANT SPECIES AND NON-PLANT MATERIAL
PREBURN, YR01 and YR02



SPECIES CODE	% RELATIVE COVER PRE	YR01	YR02
SPAI	60.4	47.2	53.6
BRMA1	33.8	39.6	39.1

FIGURE 2. % RELATIVE COVER OF TWO DOMINANT SPECIES
PREBURN, YR01 and YR02



SPECIES CODE	SCIENTIFIC NAME	COMMON NAME	HABIT
SPAI	*Sporobolus airoides*	Alkali Sacaton	native, perennial grass
BRMA1	*Bromus madritensis ssp. rubens*	Red Brome	non-native, annual grass

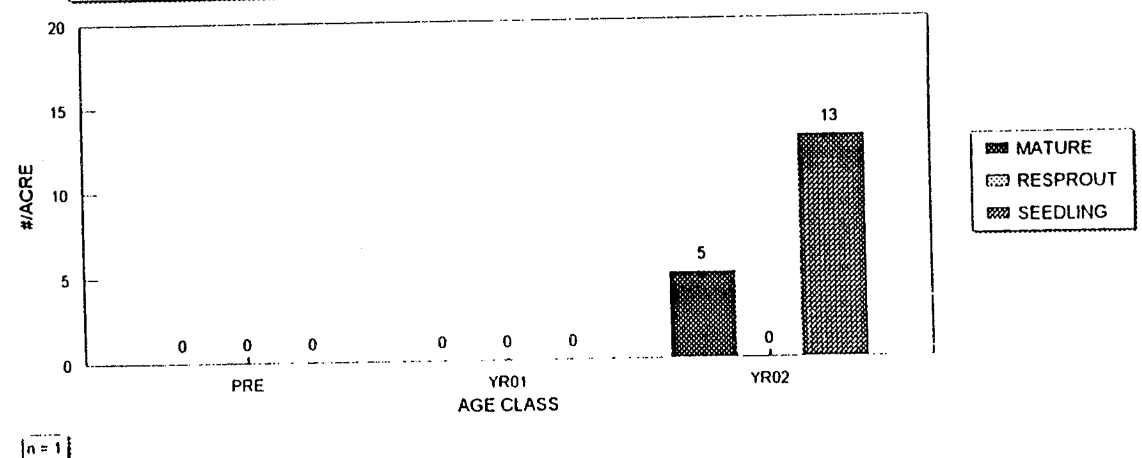
NON-PLANT includes litter, bare ground and rock

COMPARISON OF PREBURN AND POSTBURN DATA FROM SACATON GRASS TRANSECT, BSPAI1D01 01

BRUSH DENSITY (#/ACRE) OF Baccharis sergiloides

AGE CLASS	PRE	YR01	YR02
MATURE	0	0	5
RESPROUT	0	0	0
SEEDLING	0	0	13

FIGURE 3. BRUSH DENSITY OF Baccharis sergiloides (Desert Baccharis)
PREBURN, YR01 and YR02



MATURE: a shrub that is able to produce flowers and seeds

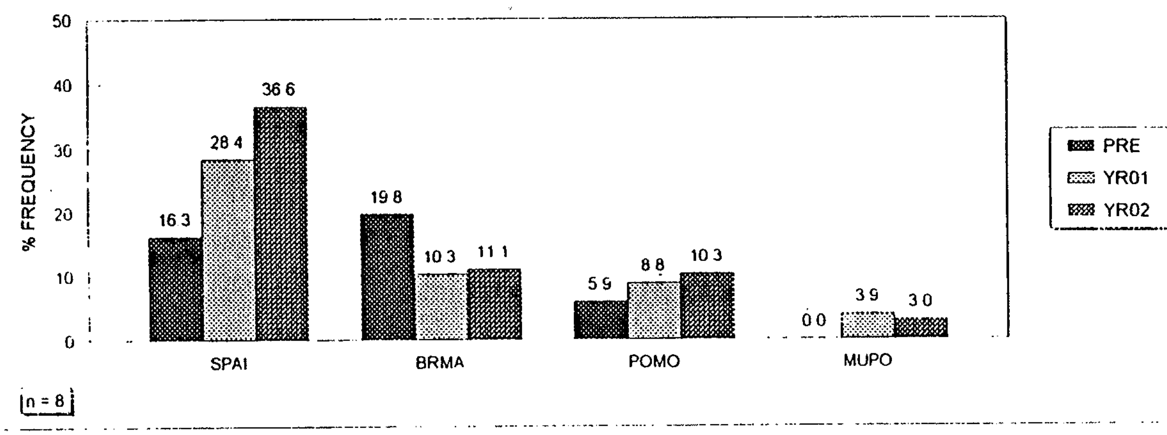
RESPROUT: a shrub that has resprouted after being top-killed by fire or another disturbance

SEEDLING: a shrub species without a burl that is too immature to flower

COMPARISON OF FREQUENCY AND RELATIVE COVER PRE AND POSTBURN OF SELECTED GRASS SPECIES, TRANSECTS BTARA1D06 01 - 08

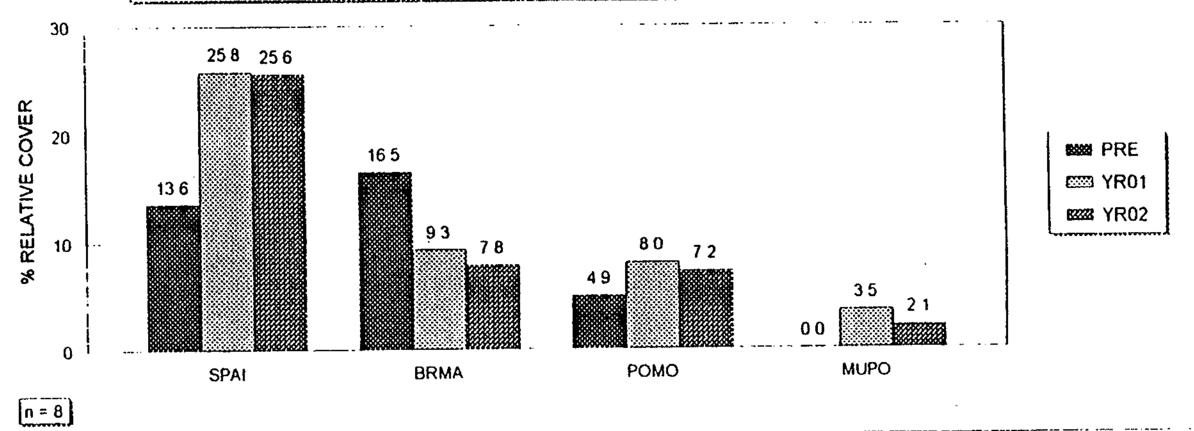
SPECIE CODE	% FREQUENCY PRE	YR01	YR02
SPAI	16.3	28.4	36.6
BRMA	19.8	10.3	11.1
POMO	5.9	8.8	10.3
MUPO	0.0	3.9	3.0

FIGURE 4. % FREQUENCY OF SELECTED GRASS SPECIES
PREBURN, YR01 and YR02



SPECIE CODE	% RELATIVE COVER PRE	YR01	YR02
SPAI	13.6	25.8	25.6
BRMA	16.5	9.3	7.8
POMO	4.9	8.0	7.2
MUPO	0.0	3.5	2.1

FIGURE 5. % RELATIVE COVER OF SELECTED GRASS SPECIES
PREBURN, YR01 and YR02

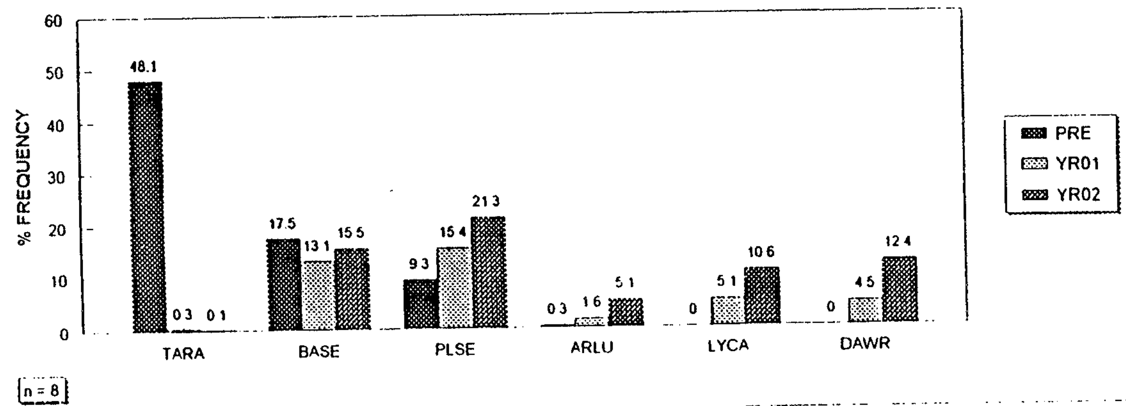


SPECIE CODE	SCIENTIFIC NAME	COMMON NAME	HABIT
SPAI	*Sporobolus airoides*	Alkali Sacaton	native, perennial grass
BRMA	*Bromus madritensis ssp. rubens*	Red Brome	non-native, annual grass
POMO	*Polypogon monspeliensis*	Rabbitfoot Grass	non-native, annual grass
MUPO	*Muhlenbergia porterii*	Muhly	native, perennial grass

COMPARISON OF FREQUENCY AND RELATIVE COVER PRE AND POSTBURN OF SELECTED BRUSH SPECIES, TRANSECTS BTARA1D06 01 - 08

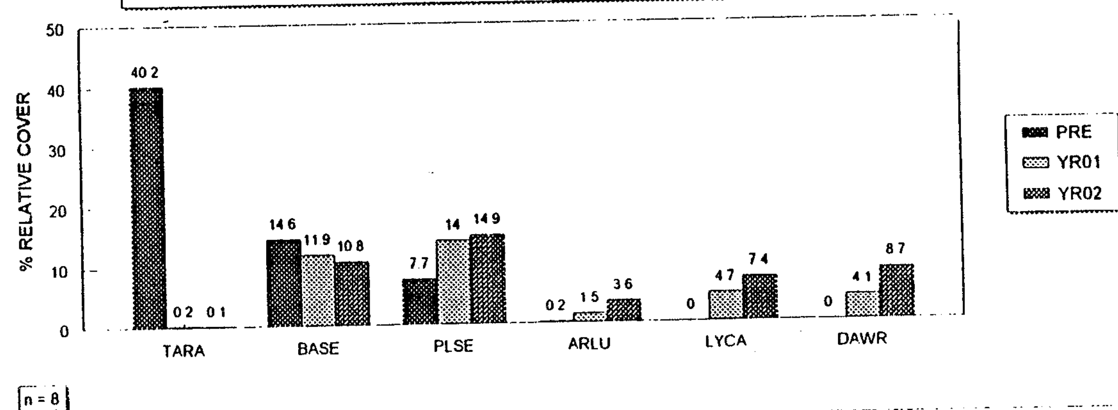
SPECIE CODE	% FREQUENCY PRE	YR01	YR02
TARA	48.1	0.3	0.1
BASE	17.5	13.1	15.5
PLSE	9.3	15.4	21.3
ARLU	0.3	1.6	5.1
LYCA	0	5.1	10.6
DAWR	0	4.5	12.4

FIGURE 6. % FREQUENCY OF SELECTED BRUSH SPECIES
PREBURN, YR01 and YR02



SPECIE CODE	% RELATIVE COVEF PRE	YR01	YR02
TARA	40.2	0.2	0.1
BASE	14.6	11.9	10.8
PLSE	7.7	14	14.9
ARLU	0.2	1.5	3.6
LYCA	0	4.7	7.4
DAWR	0	4.1	8.7

FIGURE 7 . % RELATIVE COVER OF SELECTED BRUSH SPECIES
PREBURN, YR01 and YR02



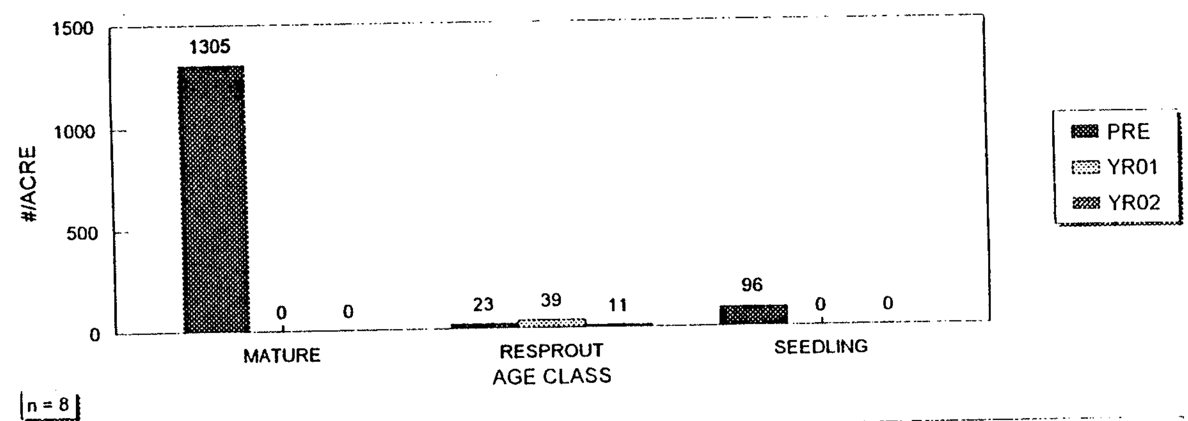
SPECIE CODE	SCIENTIFIC NAME	COMMON NAME	HABIT
TARA	*Tamarix ramosissima*	Tamarisk	non-native shrub
BASE	*Baccharis sergiloides*	Desert Baccharis	native shrub
PLSE	*Pluchea sericea*	Arrow weed	native shrub
ARLU	*Artemisia ludovichiana*	Silver wormwood	native shrub
LYCA	*Lythrum californicum*	California loosestrife	native sub-shrub
DAWR	*Datura wrightii*	Jimson Weed	native sub-shrub

COMPARISON OF BRUSH DENSITY PRE AND POSTBURN OF SELECTED BRUSH SPECIES, TRANSECTS BTARA1D06 01 - 08

BRUSH DENSITY (#/ACRE) OF Tamarix ramosissima

AGE CLASS	1991 PRE	1993 YR01	1994 YR02
MATURE	1305	0	0
RESPROUT	23	39	11
SEEDLING	96	0	0

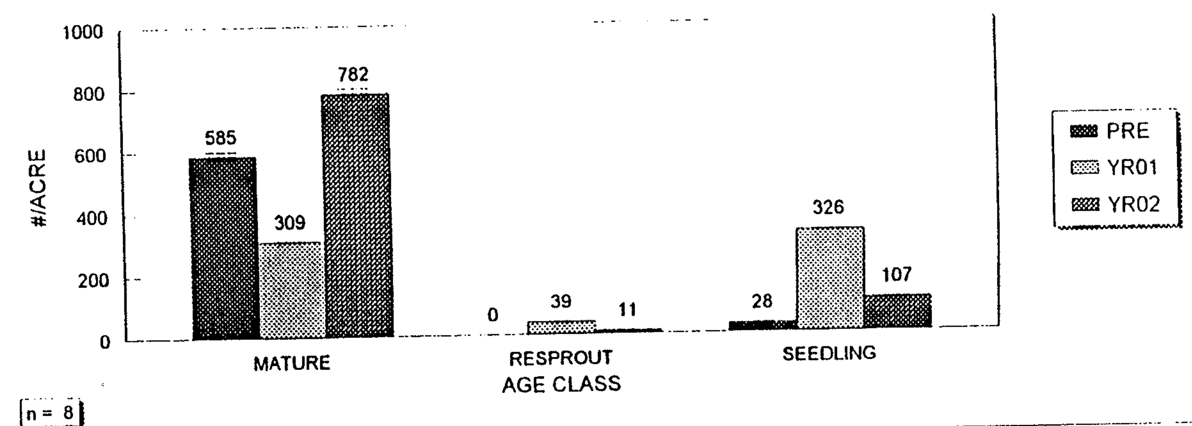
FIGURE 8. BRUSH DENSITY OF Tamarix ramosissima
PREBURN, YR01 and YR02



BRUSH DENSITY (#/ACRE) OF Baccharis sergiloides

AGE CLASS	1991 PRE	1993 YR01	1994 YR02
MATURE	585	309	782
RESPROUT	0	39	11
SEEDLING	28	326	107

FIGURE 9. BRUSH DENSITY OF Baccharis sergiloides (Desert Baccharis)
PREBURN, YR01 and YR02

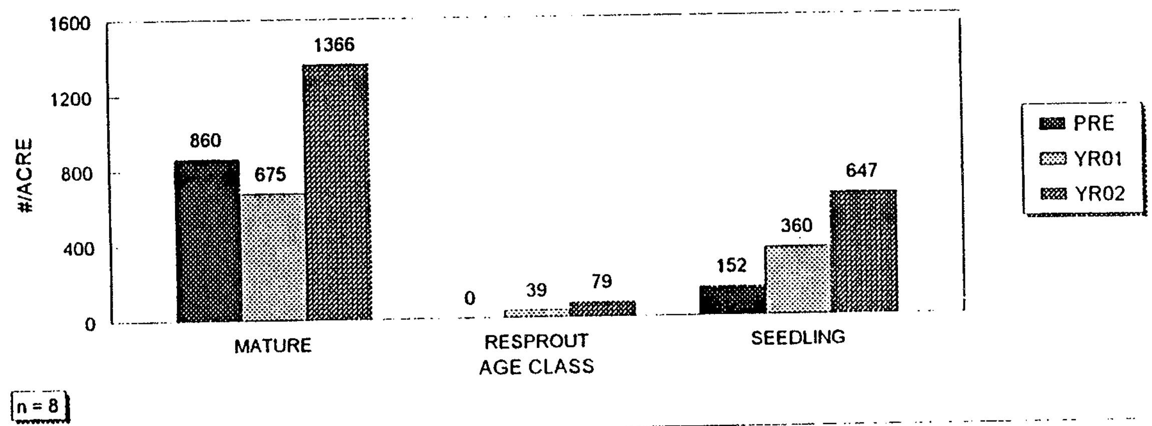


COMPARISON OF BRUSH DENSITY PRE AND POSTBURN OF SELECTED BRUSH SPECIES, TRANSECTS BTARA1D06 01 - 08

BRUSH DENSITY (#/ACRE) OF Pluchea sericea

AGE CLASS	1991 PRE	1993 YR01	1994 YR02
MATURE	860	675	1366
RESPROUT	0	39	79
SEEDLING	152	360	647

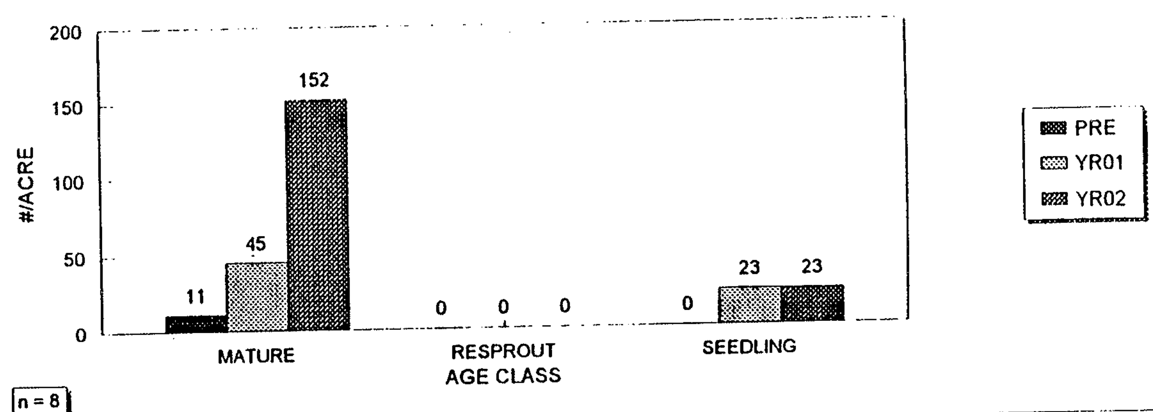
FIGURE 10. BRUSH DENSITY OF Pluchea sericea (Arrow weed)
PREBURN, YR01 and YR02



BRUSH DENSITY (#/ACRE) OF Artemisia ludoviciana

AGE CLASS	1991 PRE	1993 YR01	1994 YR02
MATURE	11	45	152
RESPROUT	0	0	0
SEEDLING	0	23	23

FIGURE 11. BRUSH DENSITY OF Artemisia ludoviciana (Silver wormwood)
PREBURN, YR01 and YR02



Appendix D - Species Code List

Species Code List FMH Data - LAME
Printed on 11/10/94 at 11:22:42 am

Code	Nat.	Perennial	Genus	Species	Subspecies	Variety	Common name
ACGR1	Y	Y	Acacia	greggii			Cat's Claw
AGVI1	N	Y	Agrostis	viridis			Water Bent
AGXX1	N	Y	Agrostis	species uncertain			
ALGA1	N	N	Algae				
AMDU1	Y	Y	Ambrosia	dumosa			Ragweed
AMTE1	Y	N	Amsinckia	tessellata			Fiddleneck
ARLU1	Y	Y	Artemisia	ludovichiana			Silver Worm Wood
BARE1	--	--	* Bare ground	soil particles <1" diam.			Bare Ground
BASE1	Y	Y	Baccharis	sergiloides			Desert Baccharis
BEJU1	Y	Y	Bebbia	juncea			Sweet Bush
BRAR1	Y	N	Bromus	arizonicus			Arizona Brome
BRCA1	Y	Y	Bromus	carinatus			California Brome
BRMA1	N	N	Bromus	madritensis	rubens		Red Brome
BRTE1	N	N	Bromus	tectorum			Cheat Grass/Downey Brome
CAXX1	N	N	Carex	species uncertain			
CECA1	Y	N	Centaurium	calycosum			Centaury
CHLI1	Y	Y	Chilopsis	linearis	arcuata		Desert Willow
CHPO1	Y	Y	Chamaesyce	polycarpa			
CHVI1	N	N	Chloris	virgata			
CIMO1	Y	N	Circium	mohavaensis			Mohave Thistle
CINE1	Y	N	Cirsium	neomexicanum			Desert Thistle
COCA1	N	N	Conyza	canadensis			Horseweed
CUPA1	Y	Y	Cucurbita	palmata			Coyote Melon
CYDA1	N	Y	Cynodon	dactylon			Bermuda Grass
DAWR1	Y	N	Datura	wrightii			Indian Apple
DEXX1	Y	N	Descaurainia	species uncertain			was unknown crucifer
DUXX1	Y	Y	Dudleya	species unknown			
ECEN1	Y	Y	Echinocereus	engelmannii			Hedgehog Cactus
EMPE1	Y	N	Emmenanthe	penduliflora			Whispering Bells
ENFA1	Y	Y	Encelia	farinosa			Brittle Brush
ENVI1	Y	Y	Encelia	virginensis			Virgin River Encelia
EPNE1	Y	Y	Ephedra	nevadensis			Nevada Ephedra
ERCI1	N	N	Erodium	cicutarium			Red-stemmed Filaree
ERDE1	Y	Y	Eriogonum	deflexum			Skeleton Weed
ERER1	Y	N	Eriastrum	eremicum			Desert Eriastrum
ERFA1	Y	Y	Eriogonum	fasiculatum	polifolium		California Buckwheat
ERIN1	Y	Y	Eriogonum	inflatum			Desert Trumpet
ERTE1	Y	N	Erodium	texanum			Storksbill
ERWR1	Y	Y	Eriogonum	wrightii			
FECY1	Y	Y	Ferocactus	cylindraceus			Barrel Cactus
GNST1	Y	N	Gnaphalium	stramineum			Everlasting
GRAS1	N	N	Unknown grass	species			
HEMU1	Y	Y	Heliomeris	multiflora		nevadensis	Golden-eye
HOJU1	Y	Y	Hordeum	jubatum			Foxtail Barley
HOMU1	N	N	Hordeum	murinum	leporinum		Foxtail
HYSA1	Y	Y	Hymenoclea	salsola			Cheese Bush
JUAC1	Y	Y	Juncus	acutus	leopoldii		Painfull Rush
JUBU1	Y	Y	Juncus	bufonius			Toad Rush
JUXX1	Y	Y	Juncus	species unknown			
JUXX2	Y	Y	Juncus	species unknown	flat-stemmed		
JUXX3	Y	Y	Juncus	species unknown	round-stemmed		
KACA1	Y	N	Kallstroemia	californica			
LASE1	N	N	Lactuca	serriola			Prickly Lettuce

LATR1	Y	Y	Larrea	tridentata			Creosote Bush
LEFL1	Y	N	Lepidium	flavum			Yellow Peppergrass
LEFR1	Y	N	Lepidium	fremontii			Peppergrass
LITT1	--	--	* Litter	dead plant parts other	than wood; cones,	seeds, bark, needles	detached leaves
LYAN1	Y	Y	Lycium	andersonii			Wolfberry
LYCA1	Y	Y	Lythrum	californicum			Loosestrife
MAFA1	Y	Y	Marah	fabaceus		agrestis	Manroot/Wild Cucumber
MICA1	Y	Y	Mimulus	cardinalis			Scarlet Monkey Flower
MIGU1	N	Y	Mimulus	guttatus			

Continued

Species Code List FMH Data - LAME
Printed on 11/10/94 at 11:22:42 am

Code	Nat.	Perennial	Genus	Species	Subspecies	Variety	Common name
MIPI1	Y	N	Mimulus	pilosus			Monkey Flower
MUPO1	Y	Y	Muhlenbergia	porteri			
NIOB1	Y	Y	Nicotiana	obtusifolia			
OECA1	Y	Y	Oenothera	caespitosa		marginata	Evening Primrose
OPAC1	Y	Y	Opuntia	acanthocarpa			Buckhorn Cholla
OPBA1	Y	Y	Opuntia	basilaris			Beavertail Cactus
OPBI1	Y	Y	Opuntia	bigelovii			Teddy-bear Cholla
ORLU1	Y	Y	Orobanche	ludoviciana			Broomrape
PEEM1	Y	N	Perityle	emoryi			Emory Rock Daisy
PHCA1	Y	Y	Phoradendron	californica			Desert Mistletoe
PLSE1	Y	Y	Pluchea	sericea			Arrow-weed
POFR1	Y	Y	Populus	fremontii	fremontii		Fremont's Cottonwood
POMO1	N	N	Polypogon	monspeliensis			Rabbitfoot Grass
PRGL1	Y	Y	Prosopis	glandulosa		torreyana	Mesquite
PRPU1	Y	Y	Prosopis	pubescens			Screwbean Mesquite
ROCK1	--	--	* Rock	mineral particles	>1" diameter		
SACO1	Y	N	Salvia	columbariae			Chia
SAEX1	Y	Y	Salix	exigua			Narrow-leaved Willow
SAGO1	Y	Y	Salix	gooddingii			Goodding's Willow
SAHI1	Y	Y	Sarcostemma	hirtellum			Purple Twining Milkweed
SCXX1	Y	Y	Scirpus	species unknown			Sedge
SOAS1	N	N	Sonchus	asper	asper		Prickly Sow Thistle
SPAI1	Y	Y	Sporobolus	airoides			Alkali Sacaton
SPAM1	Y	N	Sphaeralcea	ambigua			Desert-mallow
STLI1	Y	Y	Stillingia	linearifolia			Linear-leaved Stillingia
STPA1	N	N	Stephanomeria	pauciflora			Wire Lettuce
TARA1	N	Y	Tamarix	ramosissima			Tamarisk
TYAN1	Y	Y	Typha	angustifolia			Nail Rod
VUOC1	Y	N	Vulpia	octoflora			Slender Fescue
WATR1	--	--	* Water	permanent body of water	or running water	present 6 mos/yr or	more
WOOD1	--	--	* Wood	dead and downed twigs,	tree stumps,	branches in and	above the litter
YUSH1	Y	Y	Yucca	schidigera			Mohave Yucca

End of data

As the nation's principal conservation agency, the Department of the Interior has the responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The Department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-190 November, 1996